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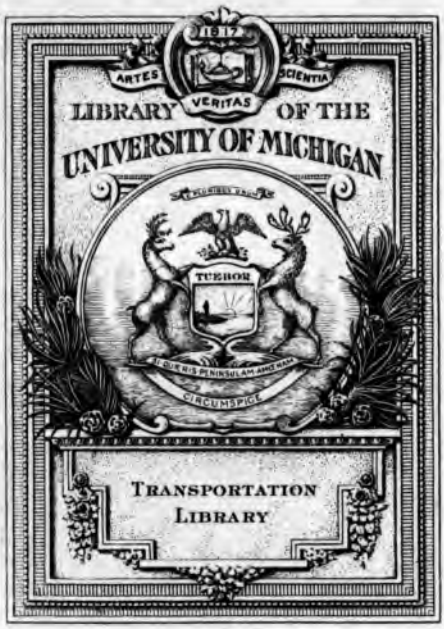

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The Signalman and His Work

The Signalman and His Work

By Kenneth L. Van Auken

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Foreword

THE story of how man has wrested from nature its secrets and applied them for the benefit of the human race is an ever-lengthening-out story of the manner in which man has risen from savagery and barbarism to that state of society which we enjoy today and which we term civilization. We have made progress as we have accumulated knowledge, and when we began the distribution of knowledge we accelerated this progress.

The fact that there is a certain amount of information in the world becomes of value only when it is made of utmost use. Undoubtedly this was the underlying thought at the recent Convention of our Brotherhood, and the thought most immediately in our minds was that we as an organization would grow and expand and develop in just such proportion as our individual members added to their fund of knowledge of the art of signaling and its practical application.

Eighty years ago Hugh Miller, the Scotch stonemason and quarryman, who became a famous geologist, wrote "The Old Red Sandstone," and in this book he said, "And do not let any class get ahead of you in intelligence." The high standard set by the railroad signalmen is very generally recognized. What we did in our action at the Convention in regard to an educational program was with the idea of increasing the knowledge of signal service.

This book, the first of a series to be issued under the direct supervision of our Brotherhood, is but a beginning of our general educational plan. Grand Lodge officers and members of the Grand Executive Board have carefully gone over the manuscript of this book and made many suggestions, which the author acknowledged as of great value. Further suggestions will, of course, be welcomed from any of you, and necessary additions incorporated in subsequent editions.

We have only one thought to add in connection with this, the first book of the Brotherhood: It should be read by each member of our organization; and we feel sure that you who read this will do your best to further its reading by your friends and associates.

Edited and published at Chicago, July 1st, 1921, acting under the instructions of the Convention of October, 1920.

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General Railway Signal Company's A-P-B Signals.

CHAPTER I

THE FUNDAMENTALS OF SIGNALING

THE purpose of signaling is to facilitate and expedite traffic with increased safety. The great need is facility—or, in other words, greater traffic capacity. Formerly, automatic block was installed primarily to increase safety; now, in a large majority of cases, signaling is installed to facilitate traffic and thus effect economical operation. All modern signaling has a high degree of safety, but the safety factor in itself is of secondary importance.

It is to prevent delays to traffic that we expend the utmost care upon the maintenance of signals, in order that they may be kept in condition to operate properly, and with the least possible number of failures, even on the safe side. A signal indicating "stop" because of a defect in maintenance causes unnecessary delays, which mean the holding up of traffic, wear and tear on equipment, and extra power spent and coal wasted in starting trains.

Definition of Signaling—Signaling is the control of railway traffic by means of fixed signals. By fixed signals are meant those located permanently at given points, as contrasted with hand or other signals which are not restricted to any particular points on the road.

Types of Signaling—There are two grand divisions of signaling: (1) block signaling, and (2) interlocking. Block signaling pertains to the spacing of trains

moving in the same or in opposite directions on the same track.

Interlocking is the means for routing trains over conflicting routes, as at crossings, junctions and terminals; or over routes which are not always intact or lined up for trains, as draw bridges, etc. The standard code definition for interlocking is: "An arrangement of switch, lock and signal appliances so interconnected that their movements must succeed each other in a predetermined order." For instance, a switch or derail must be locked in its correct position before the signal can be unlocked so that it can be cleared. Then, if the enginemen always observe and obey the signal indications, it will be impossible for a train to be derailed or to collide with another on a conflicting route. The leverman is prevented from manipulating the various levers improperly, first, by mechanical locking between the several levers, and, in addition, by various combinations of electric locking—detector, approach, route, etc.

The table below gives in concrete form a general idea of the fundamental systems of block signaling:

Types of Signaling

1. Time interval.
2. Space interval.
   a. Manual block.
   b. Controlled manual block.
   c. Automatic block.

Time Interval—The time-interval system is the old telegraphic block system. In handling trains by this method, it was only attempted to prevent a following train from leaving a station until after a certain pre-

scribed time, usually ten minutes, had elapsed, or to prevent a train from leaving a station when an approaching train had already left the station in advance. The old telegraphic block was not a block system in the strictest sense of the word.

The only difference between telegraphic block and manual block is that in the former the operator displayed the signal at "stop" for a certain time, while in the latter the signal is held at "stop" until the train has passed out of the block. In both cases trains operate under (1) book of rules, (2) time table, and (3) train orders. The great danger of the former is that a train slowing down or stopping for any cause can be overtaken by a following train before the flagman can go back far enough to protect his train.

Space Interval—The space-interval system affords a definite space interval between trains as traffic conditions may require from time to time. The big advantage of the space interval, of course, is that in case a train is delayed, the following train is prevented from running it down, provided the signals have indicated properly and have been obeyed; while with the time interval, if a train is delayed, a following train might be released, and, failing to see the flagman, or the flagman failing to protect his train properly, be permitted to run into the rear of the first train.

Manual Block—The manual block system was the first improvement over the time-interval system of signaling. In this system, block stations are located at various intervals along the railway as traffic may require; and at each of these block stations is a signal (ordinarily having an arm for each direction) con-

trolled by the operator at that point. The operator manipulates his signals in accordance with instructions or information received by telegraph or telephone from the train dispatcher or from the operators at block stations on either side.

Failure of one operator properly to execute instructions or to display his signal may cause an accident.

Controlled Manual Block—The standard code definition of this system is: "A manual block system safeguarded by the addition of electric locks, attached to the signal levers and controlled from the adjoining block stations, so arranged that a 'clear' signal cannot be displayed to admit a train into a block without the simultaneous action and consent of the signalmen at both ends of the block."

The main characteristic of this system is some form of electric locking extending from block station to block station and so arranged that the operators at each end of the block must simultaneously manipulate a key, push button or some similar device, so that the signal can be cleared.

There are numerous adaptations of the controlled manual block system, of which the following are typical:

A. Lock and block system (a name commonly used for the controlled manual block system).

B. Staff system.

C. Electric locks on levers of adjacent interlocking machines, the locks being controlled in the same manner as in "A" and "B" and communications being by bell code or telephone.

The track-trip arrangement was a crude form of automatic block. Controlled manual block with track

circuits is more properly known as semi-automatic block, but has been little used. It costs as much as automatic and there is practically nothing to be gained by imposing lever control except in certain very rare cases.

The principal disadvantage of the controlled manual system is that it is subject to failures of the human element, and a "clear" signal does not necessarily indicate that the block is unoccupied, track intact, and switches in proper position.

Automatic Block Signals—In the automatic block system, the signals are worked entirely by mechanisms which are controlled by trains or by certain conditions affecting the use of a block—such as a misplaced switch, a broken rail, etc. The basis of all systems of automatic block is a track circuit control. The track is divided up into series of insulated sections called track circuits, with one or more sections between each two adjacent signals. In each section there is a track circuit. Current flows through a wire from the track battery located at one end of a section to one rail, through the rail to the opposite end of the insulated section, and through a wire to the track relay, and then back to the return rail and through the rail and a battery wire to the battery again. (Sometimes there is more than one track circuit to a block section.)

When the track circuit current is closed (unoccupied) the track relay is energized, thus closing the local battery circuit at the signal, provided the signal apparatus is working correctly.

Anything which affects the track circuit in such a way as to take energy from the track relay also

breaks the local circuit at the signal, and this allows the signal to come to the "stop" or "caution" indication by gravity. The signals are only held at the "clear" position as long as there is a closed circuit and current is flowing through the track relay and the signal relay.

Summarizing, the principal advantages of the automatic block system are:

1. As its name implies, it operates automatically independent of the human element.
2. A "proceed" signal is displayed when conditions are safe for the passage of a train.
3. A "stop" signal is displayed if there exists any abnormal or unsafe conditions such as a train in the block, a misplaced switch, a broken rail, etc.
4. It affords a definite space interval for all kinds of traffic, depending only upon the distance from signal to signal, the minimum distance being the safe braking distance of a train or, in some cases, the maximum train length: in other words, maximum flexibility.
5. It serves as a check against failures of the human element.
6. It operates on the closed circuit principle.
7. It makes it possible to reduce to a minimum the number of operators who are only required to transmit train orders, send and receive messages, etc.

The only disadvantage of the automatic block system is that there is nothing to enforce observance of and obedience to the indications. On the other hand, a careful analysis of the I. C. C. statistics has shown that automatic signals prevent about 70 per cent of train accidents.

In lower-quadrant semaphore, the semaphore is raised to the "stop" indication by means of a counterweight. In the upper-quadrant semaphore, the weight of the blade and its counterweight will allow it to drop to the "stop" position when current is withdrawn from either the signal circuit or the track circuit.

The three-position upper-quadrant semaphore is the A. R. A. standard. The two or three-position lower-quadrant signal is still somewhat used.

Interlocking—As stated above, interlocking is a means of safely routing trains over conflicting routes, as at crossings, junctions and terminals; or over routes which are not always intact or lined up for trains, as draw bridges, etc.

According to rules, all levers are supposed to be in the normal position except when a route is set up for an approaching train. Normally, signals display their least favorable indication—derails set to derail, signals at "stop," etc. This applies to all locations—crossings, junctions, draw bridges, etc.

There are, in general, two kinds of interlocking:—(1) mechanical, and (2) power.

In mechanical interlocking the leverman exerts physical effort for operating the interlocking units. In power interlocking, the leverman manipulates levers which control the interlocking units, but the power which operates the units is supplied by electricity or compressed air.

Interlocking plants, as we know them today, are classified as follows:

1. Mechanical interlocking.
2. Electro-mechanical interlocking.

3. Electro-pneumatic interlocking.
4. Electric interlocking.

We are all so familiar with mechanical interlocking that no description is necessary. In electro-mechanical interlocking, certain units are operated by electricity to reduce the length of movable mechanical connections, such as pipe and wire lines. These plants may also include electric locking and route locking circuits—developments which have been added to safeguard the movement of trains as well as to prevent improper manipulation of levers by levermen

Electro-Pneumatic Interlocking—In electro-pneumatic interlocking, the control and indication of the units are electric, and the operation is by compressed air.

By utilizing electricity where the power requirements are comparatively low—i. e., for control and indication—and compressed air where the power requirement is heavy, but for a short duration of time —i. e., for operation of switches and signals—advantage is taken of the form of energy which is suited to the load. Electro-pneumatic interlocking provides for almost instantaneous operation of switches and signals.

Electric Interlocking—In electric interlocking, control, indication and operation of the units are through electrical circuits and electrical power.

The development of electro-pneumatic interlocking preceded the development of electric interlocking, because of the time element required in operating a unit. It takes time for an electric motor to speed up and develop the power to operate a unit. This drawback,

however, has been overcome in modern electric interlocking plants by provisions through which the man in the tower may start lining up an opposing route unit by unit behind a train as it passes certain sections of the plant. This gives the electric motors time to speed up and operate each unit; and when the train has finally passed the last section of its route, the opposing route will be practically all lined up with the exception of the signals. Many of our large passenger terminals are operated satisfactorily by electric plants.

Automatic Train Stops—There has been some confusion as to the exact difference between automatic stops and automatic train control. Automatic train stops are designed to give a "stop" action only, and therefore they correspond to the "stop" or "danger" signal. When the air is applied and the train is stopped, it is not necessary for the engineman to touch his air control. In case he is incapacitated or does not see a signal, the automatic train stop is designed to take his place. Automatic train stops may be so arranged that the engineman cannot go ahead until after the train has come to a complete stop, or that after the air has once been applied, he can regain control and use his own judgment as to how far he should reduce his speed before proceeding to the next signal, or point of control of the next automatic stop contact.

As ordinarily installed at present, the automatic stop is merely an adjunct to enforce obedience to signal indications. By means of suitable circuits it may also be utilized in connection with time-element con-

trol, as on the New York subways, where trains are permitted to close-up at stations at reduced speeds.

Automatic Train Control—Automatic train control is designed to give several different speeds corresponding to the "clear," "caution" and "stop" indications given by automatic block signals.

When a train approaches a point where the signal would be at "caution," the brakes are applied without any action by the engineer if the train is going faster than a predetermined rate of speed; and the train is slowed down until it comes to the "caution" speed, after which the air is released automatically. At places where there is a three-block indication instead of a two-block indication, speed control may be so arranged, theoretically, as to control the speed of the train for three definite limits, depending upon the condition of the track in advance.

In general, automatic stops and automatic train control are operated by means of (1) trips, (2) ramps, (3) brushes, (4) induction coils, and (5) track control governed by track circuit.

Ramps, trips, brushes or induction coil controls located at certain points along the roadway may break through track circuit or signal relays, or both, thus operating in conformity with track circuit or signal circuit conditions.

A more recently developed system provides coils on the locomotives which pick up current by induction from current flowing in the track rails. By an ingenious arrangement of standard signaling devices, a three-position control has been secured, allowing the train at all times, even when signals are not

within the range of vision, to be under the control of the track circuit occupied by the train and the circuit next in advance.

Maintenance—There is not much that can be said upon maintenance in a general and fundamental chapter such as this. But the mention of the different systems of block signals and interlocking plants is sufficient to show the great variety of apparatus and methods, and types of control of units, with which a signalman must familiarize himself if he is to become an all-around maintainer.

In the maintenance of purely mechanical plants, we have the pipe lines and wires which form the direct moving connections between the power and the units. We have crank arms, pipe line carriers, compensators, bolt lock movements, facing point locks, and many other mechanical appliances to maintain. Creeping of track or movement of switches caused by expansion or contraction of the rails creates trouble with many of these units or mechanical devices, while snow and ice or material dropped from trains interfere with operation and must be overcome by proper attention from the signal force.

In both electro-pneumatic and electric interlockings, the signalman must be familiar with electric circuit diagrams, section, sectional-route, and approach locking, indicators, annunciators, and, in fact, all electric automatic block signaling apparatus, such as relays and signals. He must also have a fair working knowledge of power equipment, such as motor generators and compressors.

In electro-pneumatic plants, the signalman must also have a fair working knowledge of air pipe lines,

and understand, besides, the action of air in cylinders, which, through their pistons, cause the switches and signals to assume their respective positions.

In electric interlocking, the signalman must understand high voltage motors and the various geared devices through which they operate the switches and signals, and must also be familiar with the effect of line resistance on voltage where considerable power is transmitted.

An all-around signalman must be a good mechanic and must be familiar with the fundamentals of electricity and of mechanical and electrical apparatus and its operation, particularly with the various means of transmitting power—mechanical, pneumatic, electric, etc.

The enumeration above is necessarily incomplete, only touching what might be termed the high spots. It is given in this chapter merely to show the scope and importance of the signalman's work, and to show the breadth of training the signalman must have. And we have in prospect the addition of automatic stops and automatic train control, which will necessitate the still further broadening of the signalman's education, for with it will come entirely new types of apparatus, which must be maintained and kept in operation, and which will constantly present new problems to the signalman.

Mr. D. W. Helt, president of the Signalmen's Brotherhood, called attention to the problems which have piled up, one upon the other, in signal maintenance, in his testimony before the Railroad Labor Board in March, 1921, from which we quote as follows:

"While railroading in general has made astonishing progress, the progress of the signal department, the newest department in railroading, has been phenomenal.

"It was only a comparatively few years ago when signaling was introduced into this country. The first signals used were manually operated block signals and manually operated interlocking plants. The manually operated block was comparatively simple, but there was quickly added the controlled manual block, and special circuits of every kind have been added, until now we have the most complicated layouts and circuits imaginable. Mechanical interlocking was complicated enough, having locking charts which sometimes required months to work out. Yet on top of this have been added many other features, even in mechanical interlocking plants, which have doubled and redoubled their complication.

"On top of all these complications there have been added direct current automatic block signaling, electro-gas automatic block signaling and finally alternating current automatic block signaling. In addition to mechanical interlocking plants, we have electro-pneumatic interlocking plants, electric interlocking plants, and electro-mechanical interlocking plants, with the myriad electrical circuits for annunciators, route locking, detector locking, advance locking, approach locking, etc., the combination of which in different plants leads to a network of complications.

"Signals have changed from lower quadrant to upper quadrant, and finally the position light signal

has been evolved. We have progressed from two-position to three-position signals, and from one-block to three-block indications. The old absolute block has given way to different combinations of absolute or permissive block, and to the complicated absolute permissive block (A. P. B.).

"On top of these rapid developments we are now just at a point where the automatic stop and automatic train control are likely to be added. Some railroads already have installations, and I. C. C. rulings and studies are being made which may soon result in the wider adoption of these complicated appliances. The recent wreck at Porter, Indiana, will undoubtedly hasten this development and place upon the already overworked signal department the necessity for learning what will be practically an entirely new art, besides forcing upon the shoulders of the signal department the maintenance of a large additional quantity of automatic stop and automatic control circuit devices.

"From the automatic stops or automatic train control already installed, we know that the equipment will be installed in connection with the signals, and that at least 90 per cent of the work necessary in the installation, maintenance and repair of these new appliances will fall upon the signal department."

CHAPTER II

AUTOMATIC BLOCK SIGNALS

THE standard code definition for an automatic block signal is: "A block signal worked by electric or pneumatic agency, which is controlled by the passage of a train into, through and out of the block section to which the signal is connected." An automatic block signal system consists of a series of consecutive automatic block signals.

The automatic block system, like the manual block system, aims to keep a definite space interval between trains. The automatic block system, however, is different from the manual block system in that the presence of a train in the block *automatically* operates the signal, thus making the safety of operation of the signal system independent of the possible mistakes which may occur in manual block signaling, through errors or lapses of memory on the part of the signal operator.

If the modern automatic block signal system is properly maintained, and if signals are obeyed by the enginemen, two trains cannot get close enough together to collide. It is true that in most cases a train is allowed by the rules of the railroad to proceed on permissive indication into a section which may be occupied by a preceding train, after having been brought to a stop at a "stop" indication; but in that case the rules also state that the engineman must keep his train under control and be prepared to stop within his vision. This applies to double track or to trains running in the same direction on single track under the absolute permissive block system.

The First Automatic Block Signals—The first automatic block signals were controlled by track instruments. The track instrument consisted of a lever which was hit and depressed, or an electrical contact which was operated by the bending of the rails as the wheels passed over.

The Track Circuit—The accepted basic principle for control of practically all modern signal systems is the closed track circuit. The mechanism for operating the signals, which is separate from the track circuit, is also designed on the closed circuit principle. A break or short in either of these circuits allows the signal to assume the "stop" indication.

With the track circuit, failure of a rail or some part of the track will usually be indicated, causing the signal to assume the "stop" position. That is, a break in the track rail will be a break in the track circuit, under most conditions, which will prevent current from flowing through the track circuit relay, the armature of which will then drop, thus opening the signal circuit and allowing the signal to operate to "stop."

Breaks in the rails do not always operate the signal, however. If a break comes at a joint, the current may be carried around by the bond wires, and the break will then have no effect. Sometimes a break in a rail is such a small crack that there is still enough current passing through the rail, and possibly through the ballast around the break, to hold the relay armature up. It has become quite common practice, however, in track maintenance, to keep all ballast away from contact with the rails. This not only prevents leakage around the rail break, but keeps

leakage at a minimum through the ballast from rail to rail—a condition which is more likely to be serious when the ballast is wet, during heavy rains, etc. With properly maintained track, therefore, most dangerous breaks in rails will be indicated by the signal going to the "stop" position. Rail breaks at joints between the bond wires are usually not dangerous because the rail is held in place by the angle bars.

The track circuit control of trains not only gives an automatic control which is independent of the action of operators, but it gives continuous control, for the train shorts the track circuit current away from the track relay as long as the train occupies the track section. With track instruments, the train has no effect on the signals except when passing the particular point at which the track instrument is located.

Absolute and Permissive Signals—Single track signals may be controlled under the older preliminary overlap system or the more recently developed absolute permissive system. The "caution" and "clear" signal indications with these two systems mean the same thing, but the "stop" indication differs. With the older system, a train must wait a certain time at a "stop" signal and then proceed only under flag protection, the flagman preceding the train through the block. In the A. P. B. system, two kinds of signals are used—the absolute and the permissive. The absolute signal indicating "stop" means that the conductor must get in touch with the dispatcher by telephone or otherwise and proceed through the block only under his authority, or as provided in the rules. The permissive signal, operating under this system, when indicating "stop" means stop and proceed, the

same as on double track. The systems just described are for use on single track only.

With the automatic block system as used on double or multiple track, it is allowable to have two or more trains between sidings at the same time, because traffic on each track is in only one direction, the object of signaling being to expedite traffic as well as to promote safety. The closer together trains can be safely operated, the greater the amount of traffic one track will carry. With the permissive block system on a multiple track railway, trains may be started out from a division terminal as fast as the starting signal clears up behind the train in advance. In this manner freight trains may be started out only a block apart.

Multiplying Signal Protection—When automatic block signaling was first introduced, it was considered sufficient to have each signal operate in two positions only, namely, "stop" and "proceed." Then, unless there was a separate distant signal in the rear of the home signal, it was possible for two trains to come dangerously close together if the first train stopped a few feet ahead of a signal.

By using two signals—a distant signal for each home signal—safe blocking was obtained with two-position signals, but at an increased expense for signals. Where the distant signals were placed on separate poles, the additional expense was still greater.

From an economical viewpoint, at least three indications are necessary at each signal location, namely, "stop," "caution" (proceed under control—ready to stop), and "clear" (proceed at full speed). These indications are usually given in modern signal systems by three-position signals, horizontal indicating "stop,"

45 degrees indicating "caution," and 90 degrees indicating "clear." The signal at "stop" indicates that the first block in advance is occupied; the signal at "caution" indicates that the first block is clear, but that the second block in advance is occupied; while the signal at "clear" indicates that at least two blocks in advance are unoccupied. This extension of the information given the engineman not only made the operation of trains safer, but expedited traffic by allowing the engineman to regulate his speed so that he would not be stopped by constantly working up too close to a train in advance.

On some lines of dense traffic, the signal indications have been worked out to cover even a greater number of blocks. The three-position signal will give information concerning the two blocks in advance. Double-blade signals are being used to give information to the engineman on at least three blocks in advance.

Location of Signals—While this book is not intended to deal with all the details of design or layout of signal or interlocking systems, nevertheless a few words regarding the location of automatic block signals will not be out of place, as they may explain some arrangements which have puzzled signalmen. Automatic block signals should be located on a time-interval basis. In practice, the preliminary signal locations are made on a plan and profile of the railway line. Then these locations are checked up with the profile, with the location of switches, coal chutes, water stations, curves, etc., and signal locations are changed to give the best vision and the best operating results. Signals should not be placed where they will

stall heavy trains on a grade, and they should be located in advance of stretches of track where vision is obstructed. Another condition which must be considered is the distance required for a train to stop when running at high speed.

All these conditions make the actual location of each signal a separate problem. There are places, of course, where station stops are far apart, and where a railway line may be almost straight, with few heavy grades, and in places of this kind a more uniform spacing of signals may be used without any difficulty.

It is always advisable to have an absolute block signal far enough ahead of a switch so that if the switch is opened and operates the signal in front of an approaching train, the train can stop under the worst possible conditions of speed and reduced braking power caused by slippery rails.

Signals should be so located that when a train stops at a passenger station, at the end of a siding or at a coaling or water station, the engineman will have a signal in front of him and not have to make an extra stop for a signal a little further on.

Normal Indication of Signals—An automatic block signal system may be "normal-clear" or "normal-danger." The "normal-clear" system is used on a large majority of installations in this country. In this system the signal blade clears up as soon as the train passes beyond the limit of the circuits governing it, provided, of course, no other conditions are set up, such as an open switch, wheels within fouling distance on turnouts, etc. The signal indicates "proceed" when the block is unoccupied and conditions are normal.

In the "normal-danger" system, the signals normally

indicate "stop." As a train enters the approach section, the signal operates to "proceed" or "clear" if two blocks ahead are clear, or to "caution" if one block ahead is clear. If a train in advance is in the first block, the signal will remain at "stop." Almost all signal installations are "normal-clear."

A. C. and D. C. Signaling—The first electric block-signal installations were operated by direct current. The important advantages of the D. C. block system are: (1) Its wide use. (2) Its high state of development. (3) Its adaptability: In other words, it is operated by batteries which can be installed almost anywhere. Its disadvantages are: (1) Subject to interference of foreign currents. (2) More or less frequent renewal of batteries. (3) Length of ordinary track circuit limited to about 3500 feet. (4) Small currents and, consequently, small and light parts.

D. C. automatic block systems are always operated from batteries, usually R. S. A. 500 A. H. cells, and never from a D. C. transmission line, for that method would be impracticable, as economy of transmission would require high voltage, which could be reduced only by motor-generator sets or machines comprising moving parts, which, obviously, would necessitate an attendant.

Direct current is undirectional. Alternating current consists of a continuous series of positive and negative alternations, which are usually expressed by the term "frequency in cycles per second," one cycle consisting of two alternations, so that a 60 cycle current would alternate or change direction 120 times a second. In alternating current, also, voltage and current fluctuate throughout a cycle.

Signal instruments designed for one particular kind of alternating current will not be affected by foreign direct current or by alternating current of a different frequency.

NOTE: Aside from the fact that an alternating current relay is not affected by the influence of a foreign current unless it has the same "frequency" (number of alternations per second) as the signal current, is the fact that the use of A. C. eliminates batteries from the signal system, the alternating current being generated at a power plant and transmitted long distances over line wires. As alternating current can be transmitted great distances without excessive loss of power, in the A. C. system it is therefore possible to use much longer transmission circuits. Track circuits can also be longer on account of the higher voltages available. A. C. track circuits as long as 25,000 feet have been operated with success.

Induction motors are used for operating A. C. signals. These motors have no commutators nor brushes and are therefore much simpler to maintain than D. C. motors.

General Maintenance—The testing and maintenance of automatic block signals covers a very wide range. Trouble with a signal may be due to grounds, foreign current, defective track or switches, defective wiring, defective apparatus, defective bond wires, reduced ballast or tie resistance, etc.

The main problem usually is to find or locate the source of the trouble, and in many cases the correction of the trouble is a simple matter after it has once been located. For this reason it is advisable for the signalman to acquaint himself as broadly as possible

with all types of trouble other signalmen have had and the method followed in locating the trouble.

If the signalman has in mind all of the possible sources of trouble, he can start out and eliminate one after another and eventually locate the point of the defect. Most signalmen have a definite routine which they follow, as they have found from experience what defects are most likely to occur on their own sections.

The signalman should understand clearly the fundamentals of block signaling in general and also the fundamentals of the particular signals upon which he is employed. Most signalmen have this fundamental knowledge, but many of them have not analyzed it clearly enough to make if of maximum benefit to themselves.

CHAPTER III

SIGNAL ASPECTS AND INDICATIONS

THE Railway Signal Association in 1912 drew up a report upon the essentials of signaling in which it gave its recommendations as to the signals that are essential, and then included its recommendations as to what positions of the semaphore should be adopted to give these indications:

There are three signals that are essential in operation and therefore fundamental, namely:

(1) Stop.

(2) Proceed with caution.

(3) Proceed.

The fundamental, "proceed with caution," may be used with the same aspect to govern any cautionary

Scheme No. 1.

Fundamentals.

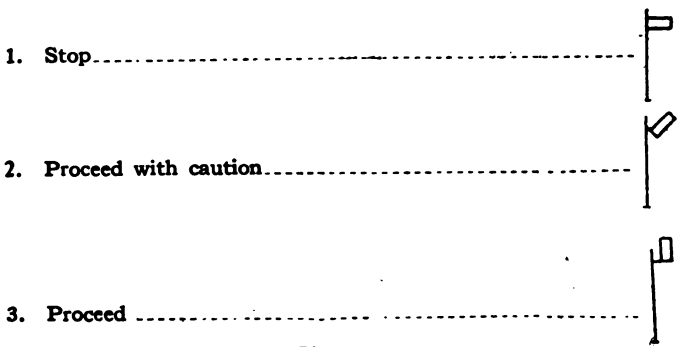


Figure 1.

movement. For example, when—

(a) Next signal is "stop."
(b) Next signal is "proceed at low speed."
(c) Next signal is "proceed at medium speed."
(d) A train is in the block.
(e) There may be an obstruction ahead.

Scheme No. 2.

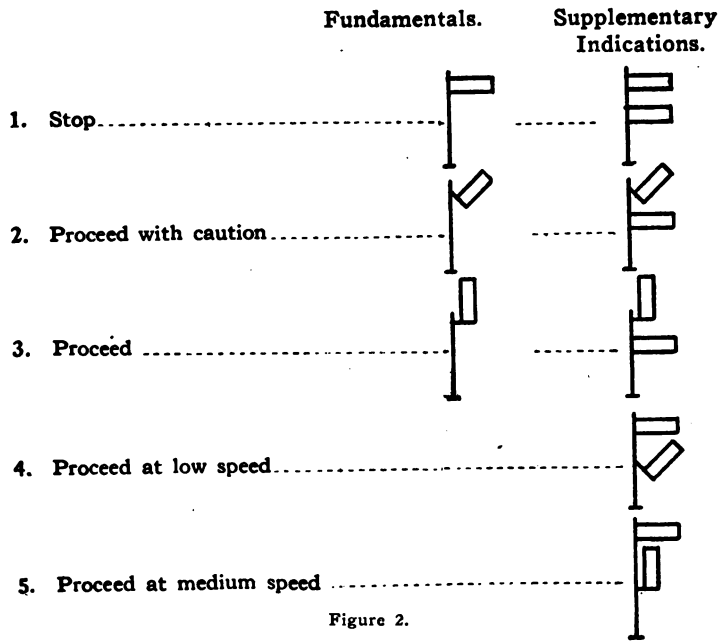


Figure 2.

There are two additional indications which may be used where movements are to be made at a restricted speed, namely:

(4) Proceed at low speed.
(5) Proceed at medium speed.

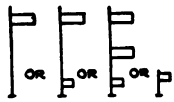
Where automatic block system rules are in effect, a

special mark of some distinctive character should be applied at the stop signal.

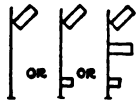
The indications adopted to cover the above fundamentals are shown in Figure 1.

Scheme No. 3.

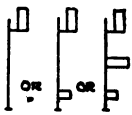
1. **Stop** .....



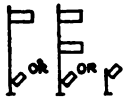
2. **Proceed with caution** .....



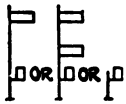
3. **Proceed** .....



4. **Proceed with caution on low-speed route**....



5. **Proceed on low-speed route** .....



6. **Proceed with caution on medium-speed route**

7. **Proceed on medium-speed route**...

8. **Reduce to medium speed**.....

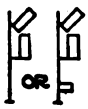


Figure 3.

As a means of designating stop signals operated under automatic block system rules, the following are suggested:

1. The use of a number plate; or

2. The use of a red marker light below and to the left of the active light; or

3. The use of a pointed blade, the blades of other

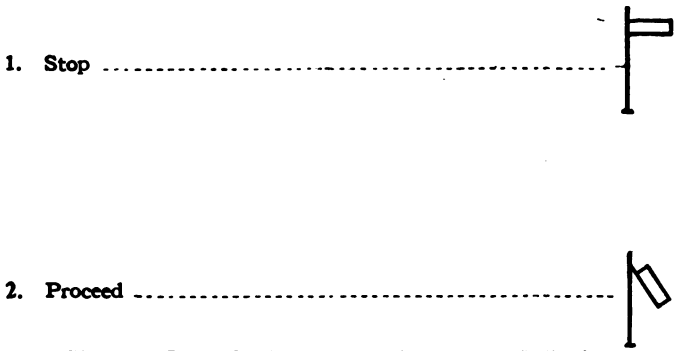


Figure 4—Lower-Quadrant Two-Position Signal Indications.

signals giving the "stop" indication having square ends; or

4. A combination of these distinguishing features.

The same means of designating stop signals operated under automatic block system rules were suggested in connection with the supplementary scheme (Figure 2) as for the fundamental scheme.

The committee also submitted a third scheme, "having in view the practice of indicating diverging routes by several arms on the same mast."

The means for designating stop signals operated under automatic block system rules under Scheme

No. 3 were the same as under Schemes No. 1 and No. 2. Scheme No. 1, upper-quadrant signals, has become so widely used that practically all railroad men now recognize the indications.

1. **Stop**

2. **Proceed with caution**

3. **Proceed**

4. **Proceed at low speed**

5. **Proceed at medium speed**

Figure 5—Lower-Quadrant Two-Blade Two-Position Signal Indications.

SIGNAL ASPECTS AND INDICATIONS

The A. R. A. fundamentals were outlined only for upper-quadrant signals. And while the present outlook seems to point towards the complete substitution of upper-quadrant for lower-quadrant signals, as yet there are a good many miles of lower-quadrant signals in operation.

The indications for a single-blade, two-position lower-quadrant signal are as shown in Figure 4.

In order to get indications on two blocks in advance, with two-position lower-quadrant signals, it is necessary to use two-blade signals, in which case the indications are as in Figure 5.

These lower-quadrant indications have been illustrated because there are still a great many lower-quadrant signals on our railroads.

It is noted, of course, that these signals all have square-end blades. Neither the shape of the blades nor their color is mentioned in these fundamentals, which have to do entirely with the positions of the signal blades.

The square-end semaphore blade, shown in Figure 6, is used for non-automatic block and interlocking home signals; and the fish-tail semaphore blade, Figure 7, is used for block and interlocking distant signals. The pointed-end semaphore blade, Figure 8, is used for automatic home signals or for train order signals. Figure 9 shows the round-end blade commonly used as a train order signal.

The light indications corresponding to "stop," "proceed with caution" and "proceed" are as follows: Red

for "stop," yellow for "proceed with caution," and green for "proceed." These are the colors adopted by the Railroad Signal Association (Signal Section A. R. A.).

On some lines it is still the practice to use a white light for "clear." This is not considered the best practice, however, because in case a colored glass roundel is broken out, a danger signal light might show

Figure 6.

Figure 7.

Figure 8.

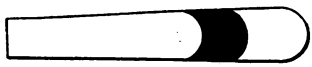


Figure 9.

white instead of red, or a caution light might show white instead of yellow.

Signal Location—The location of the signal on the right of way on either single or double track is a simple matter, as the signal pole may simply be located at the right-hand side of the track when facing in the direction of traffic. In other words, the signal which the engineer sees at the right-hand side of the track is the signal governing the movement of his train.

In single track, the signal locations for opposite directions are often placed directly across from each other, so that when the engineman sees the front of his own signal at the right-hand side of the track he at the same time sees the back of the signal for opposing traffic at the left-hand side of the track.

While there is not much danger of an engineman reading the wrong signal in single track, there is still less danger in double track. When there are more than two parallel tracks, however, there is a chance for

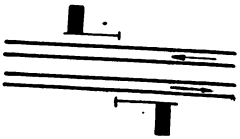


Figure 10.

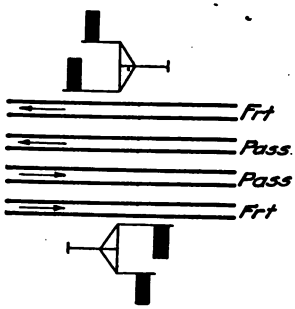


Figure 11.

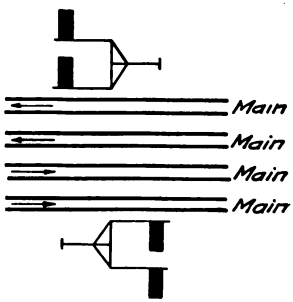


Figure 12.

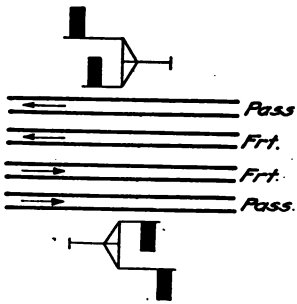


Figure 13.

confusion. The layouts shown in Figures 10, 11, 12 and 13 indicate the way in which signals are placed on poles for double and multiple tracks under different conditions. The chance for confusion is easily seen where it is attempted to signal four tracks.

The danger of reading a wrong signal has led to the wide use of signal bridges on three and four-track roads and even on double-track roads.

With a signal bridge, each signal arm can be located directly above the track it governs, and there is much less danger of confusion and mistakes than there is with signal poles. Illustrations 14, 15 and 16 show methods of arranging signals on bridges.

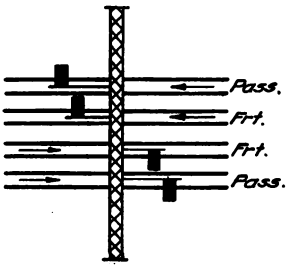


Figure 14.

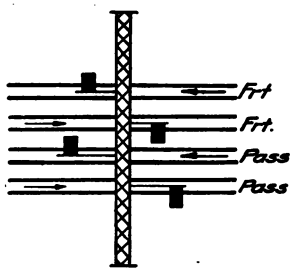


Figure 15.

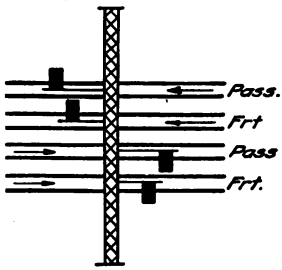
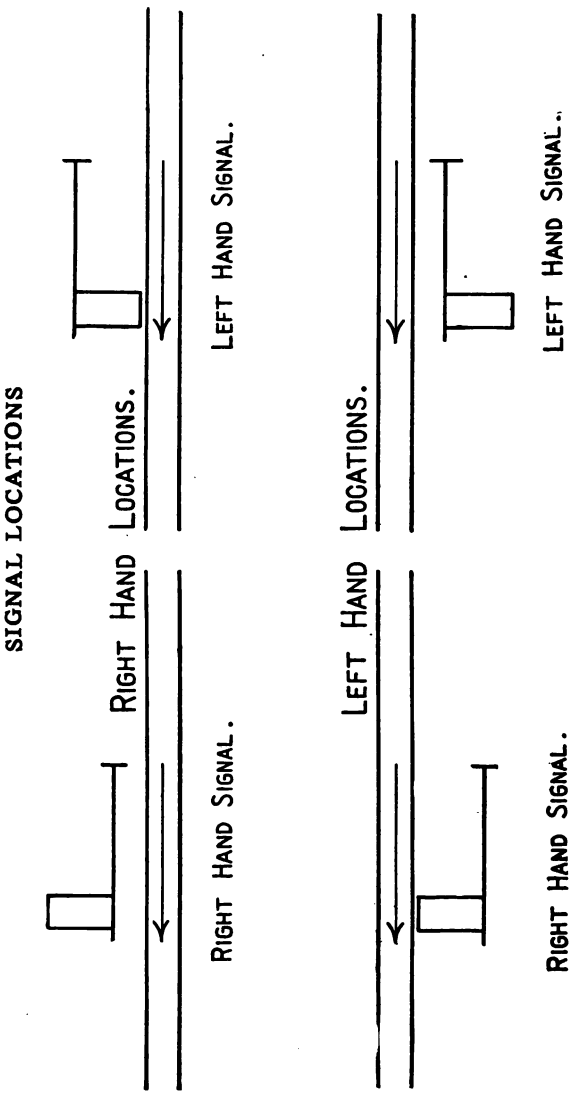


Figure 16.

In the following pages are shown symbols adopted by the Signal Section of the American Railway Association. These indicate the way to illustrate various signal layouts and conditions upon plans and maps.


SIGNAL LOCATIONS
RIGHT HAND LOCATIONS.
RIGHT HAND SIGNAL.
LEFT HAND SIGNAL.
LEFT HAND LOCATIONS.
RIGHT HAND SIGNAL.
LEFT HAND SIGNAL.

SIGNAL SYMBOLS

Operating.		Characteristics	Non-Automatic. Mechanical 1	Non-Automatic. Power 2	Slotted. (Mech.) 3	Semi-Automatic. (Power.) Stick. 4	Semi-Automatic. (Power.) Non-Stick 5	Automatic (Power) 6	Special Requires Reference to Notes. 7
Two Position Signaling.	2-Position. 0 to 60 · 0 to 70 0 to 75 · 0 to 90	A	A1	A2	A3	A4	A5	A6	A7
Three Position Signaling.	2-Position. 0 to 90	B	B1	B2	B3	B4	B5	B6	B7
	2-Position. 0 to 45	C	C1	C2	C3	C4	C5	C6	C7
	2-Position. 45 to 90	D	D1	D2	D3	D4	D5	D6	D7
	3-Position. 0 to 45 to 90	E	E1	E2	E3	E4	E5	E6	E7

SIGNAL SYMBOLS

E24 — SPECIAL - 3 POSITION NON-AUTOMATIC, 0 TO 45.
SEMI-AUTOMATIC STICK, 45 TO 90.

E25 — SPECIAL - 3 POSITION NON-AUTOMATIC, 0 TO 45.
SEMI-AUTOMATIC NON-STICK, 45 TO 90.

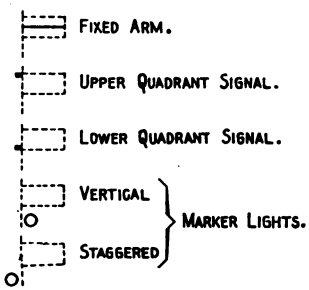
ABSOLUTE STOP SIGNAL.

DISTANT SIGNAL.

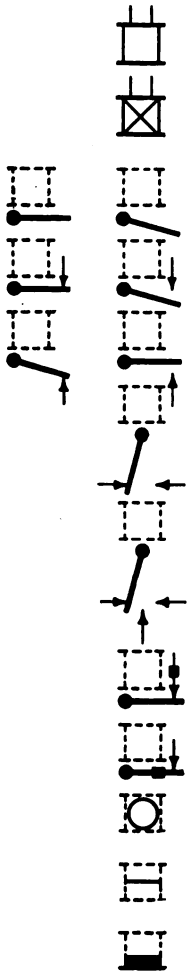
PERMISSIVE STOP SIGNAL.

TRAIN ORDER SIGNAL.

ENDS OF BLADES IN SYMBOLS ARE TO BE OF THE ACTUAL FORMS USED BY THE ROAD CONCERNED. IF NOT SPECIFIED THE ABOVE FORMS WILL BE USED ON PLANS.



RELAYS, INDICATORS AND LOCKS



D. C. Electro Magnet.

A. C. Electro Magnet.

Coil Energized or De-energized.

Neutral Front Contact – Closed or Open.

Neutral Back Contact – Closed or Open.

Polarized Armature – With Contacts.

3 – Position Armature – With Contacts.

High Current Contact.

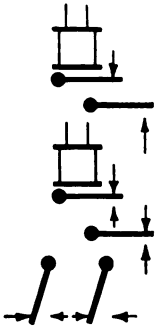
Magnetic Blow-out Contact.

Bell Attachment.

Double Winding – Specify if Differential.

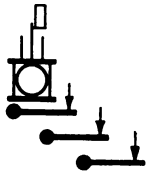
Slow Acting.

RELAYS, INDICATORS AND LOCKS



D.C. RELAY – NEUTRAL – ENERGIZED –
ONE INDEPENDENT FRONT CONTACT CLOSED –
ONE INDEPENDENT BACK CONTACT OPEN.

D.C. RELAY – POLARIZED – ENERGIZED –
TWO COMBINATION FRONT AND BACK NEUTRAL CONTACTS –
TWO POLARIZED CONTACTS CLOSED –
TWO POLARIZED CONTACTS OPEN.

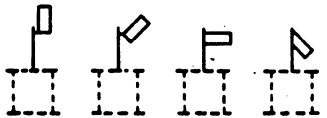


D.C. INDICATOR – SEMAPHORE TYPE – ENERGIZED –
THREE FRONT CONTACTS CLOSED –
BELL ATTACHMENT.

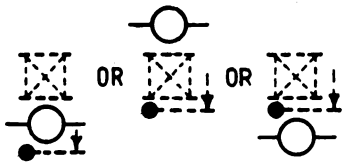
D.C. INDICATOR – SEMAPHORE TYPE – ARM HORIZONTAL –
ENERGIZED – WITHOUT CONTACTS.

RELAYS, INDICATORS AND LOCKS

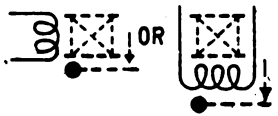
DISC TYPE INDICATOR. ○ = DISC INVISIBLE ● = DISC VISIBLE



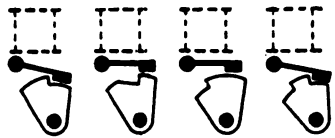
SEMAPHORE TYPE INDICATOR. = 3-POSITION.



WIRE WOUND ROTOR.

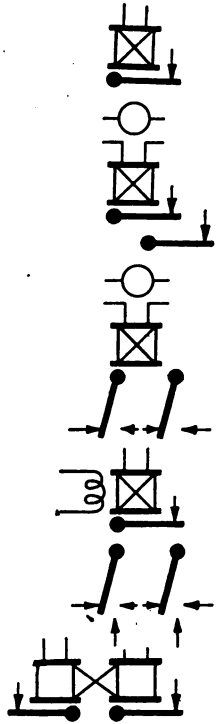


STATIONARY WINDING. = HIGH VOLTAGE WINDING.



ELECTRIC LOCK - SHOW SEGMENTS FOR LEVER IN NORMAL POSITION.

RELAYS, INDICATORS AND LOCKS



A.C. RELAY – ONE ENERGIZING CIRCUIT TYPE (SINGLE PHASE)
ENERGIZED – ONE FRONT CONTACT.

A.C. RELAY – TWO ENERGIZING CIRCUIT TYPE – ENERGIZED –
WIRE WOUND ROTOR –
TWO NEUTRAL FRONT CONTACTS.

A.C. RELAY – TWO ENERGIZING CIRCUIT TYPE – ENERGIZED –
WIRE WOUND ROTOR –
TWO POLARIZED CONTACTS.

A.C RELAY – TWO ENERGIZING CIRCUIT TYPE – ENERGIZED –
STATIONARY WINDINGS –
ONE NEUTRAL FRONT CONTACT –
TWO 3-POSITION CONTACTS.

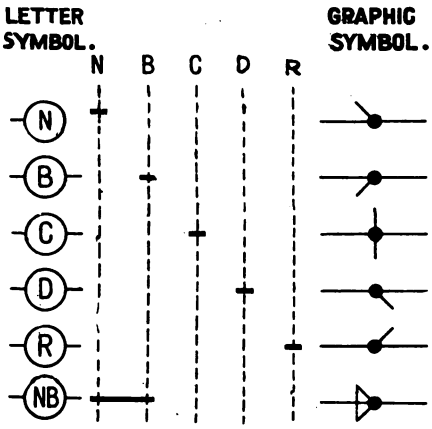
D.C. INTERLOCKED RELAY.

D.C. ELECTRIC BELL.

CIRCUIT CONTROLLERS OPERATED BY LEVERS

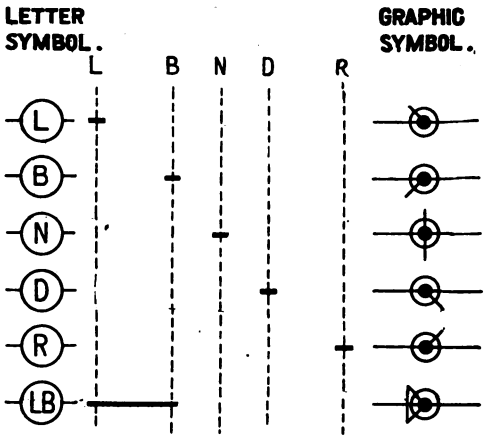
Levers with Extreme End Position as Normal.

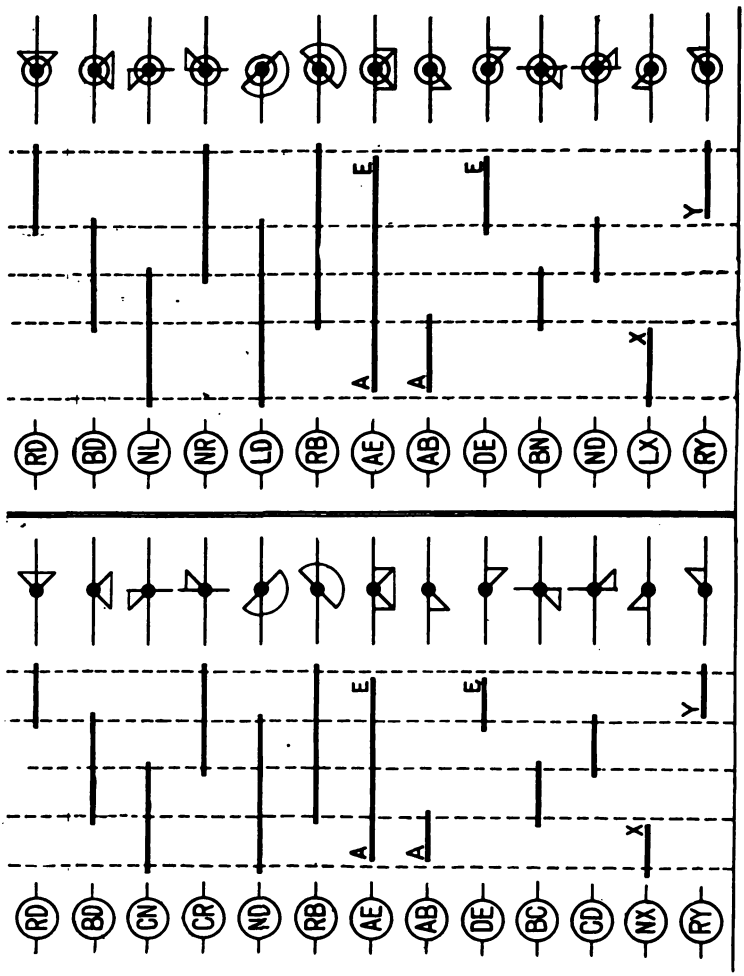
N–Full Normal Position of Lever.
B–Normal Indication Position.
C–Central Position.
D–Reverse Indication Position.
R–Full Reverse Position.



Levers with Middle Position as Normal.

N–Normal Position.
L–Full Reverse Position to the Left.
B–Indication Position to the Left.
D–Indication Position to the Right.
R–Full Reverse Position to the Right.

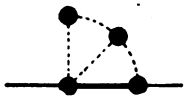



E
E
Y
A
A
X
RD
BD
NL
NR
LD
RB
AE
AB
DE
BN
ND
LX
RY
E
E
Y
A
A
X
RD
BD
CN
CR
ND
RB
AE
AB
DE
BC
CD
NX
RY

SIGNAL CIRCUIT CONTROLLERS

UPPER QUADRANT. LOWER QUADRANT.

3-POSITION SIGNALS.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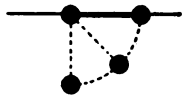

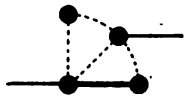
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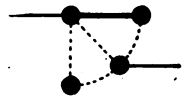

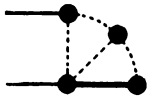
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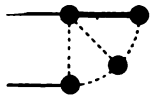
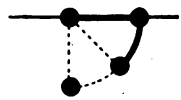
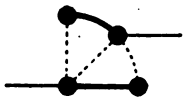


CLOSED 0° TO 45°
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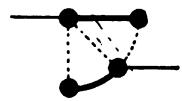
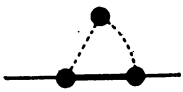


60°-70° OR 75° SIGNALS.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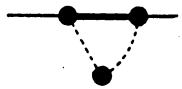
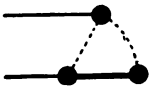
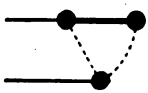
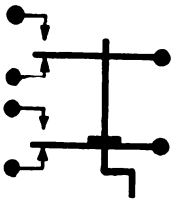
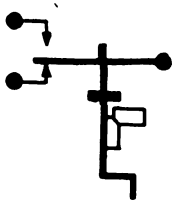



CLOSED IN CLEAR POSITION ONLY.


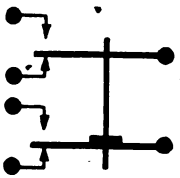
RreleaseS



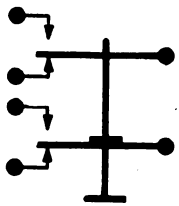
MANUAL TIME RELEASE.
(ELECTRIC)



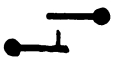
MANUAL TIME RELEASE.
(ELECTRO-MECHAN'L.)



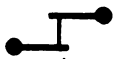
AUTOMATIC TIME RELEASE.
(ELECTRIC)



EMERGENCY RELEASE.
(ELECTRIC)



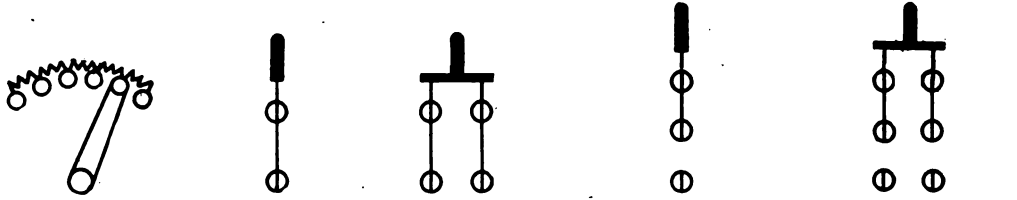
OPEN.



CLOSED.

FLOOR PUSH. LATCH CONTACT. TRACK INSTRUMENT CONTACT.

ELECTRICAL INSTRUMENTS

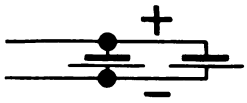


RHEOSTAT. SINGLE POLE. SINGLE THROW. DOUBLE POLE. SINGLE POLE. DOUBLE THROW. DOUBLE POLE.

QUICK ACTING CIRCUIT CONTROLLERS MAY BE DISTINGUISHED BY THE LETTER "Q"

FIXED RESISTANCE. VARIABLE RESISTANCE. FUSE.

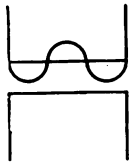
IMPEDANCE WITHOUT IRON CORE. IMPEDANCE WITH IRON CORE. CONDENSER.



CELLS IN MULTIPLE.

CELLS IN SERIES.

SPECIFY TYPE AND NUMBER OF CELLS.



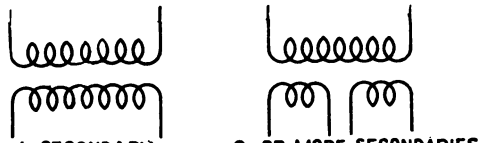
A.C. TERMINALS.

D.C. TERMINALS.

RECTIFIER.

D = DRY BATTERY.
G = GRAVITY "
P = POTASH "
S = STORAGE "

EXAMPLES: 16P, 10S, ETC.



1-SECONDARY.

2-OR MORE SECONDARIES.

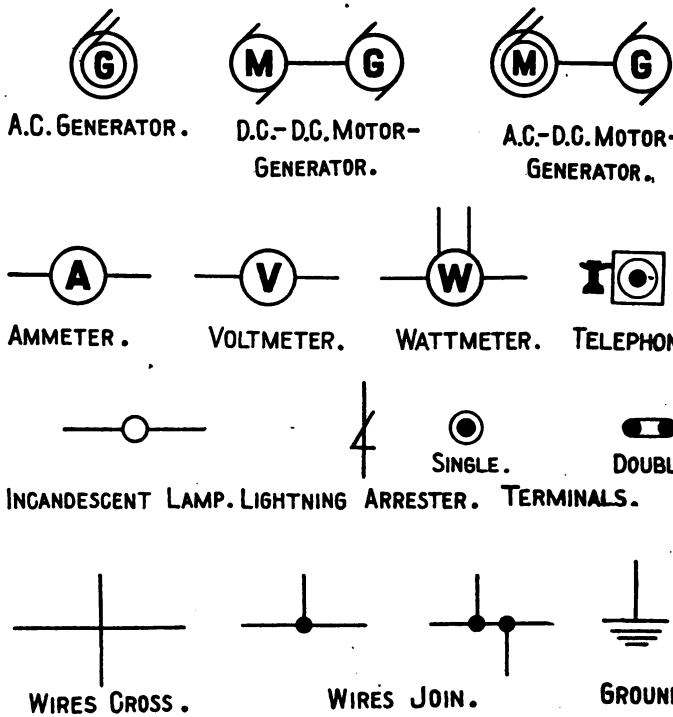
TRANSFORMERS.

D.C. MOTOR.

D.C. GENERATOR.

A.C. MOTOR.

ELECTRICAL INSTRUMENTS



A.C. GENERATOR. D.C.-D.C. MOTOR-GENERATOR. A.C.-D.C. MOTOR-GENERATOR.

AMMETER. VOLTMETER. WATTMETER. TELEPHONE.

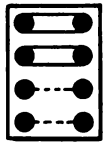
INCANDESCENT LAMP. LIGHTNING ARRESTER. TERMINALS.

WIRES CROSS. WIRES JOIN. GROUND.

"COMMON" WIRE. OTHER THAN "COMMON" WIRE.

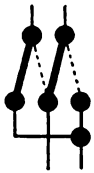
TRACK CIRCUIT WIRE. DIRECTION OF CURRENT.

CIRCUIT CONTROLLERS

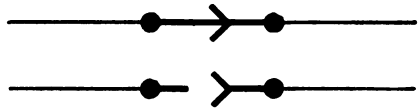


SWITCH CIRCUIT CONTROLLER.

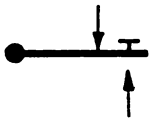
CIRCUIT CONTROLLER OPERATED BY LOCKING MECHANISM OF A SWITCH MOVEMENT.



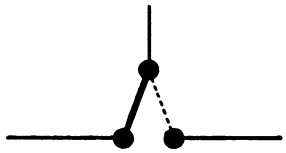
POLE CHANGING CIRCUIT CONTROLLER.



BRIDGE CIRCUIT CONTROLLER.

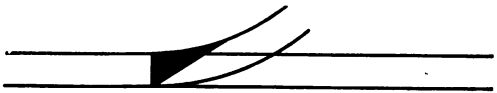


SPRING HAND KEY OR PUSH BUTTON.



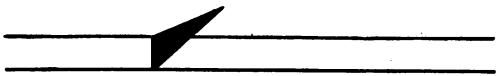
CIRCUIT SWITCH.

INTERLOCKED SWITCHES AND DERAILS



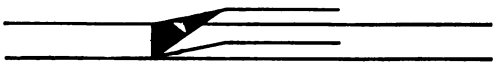
SWITCH—SET FOR TURN-OUT.

SWITCH—SET FOR STRAIGHT TRACK.



DERAIL—POINT TYPE—DERAILING.

DERAIL—POINT TYPE—NON-DERAILING.



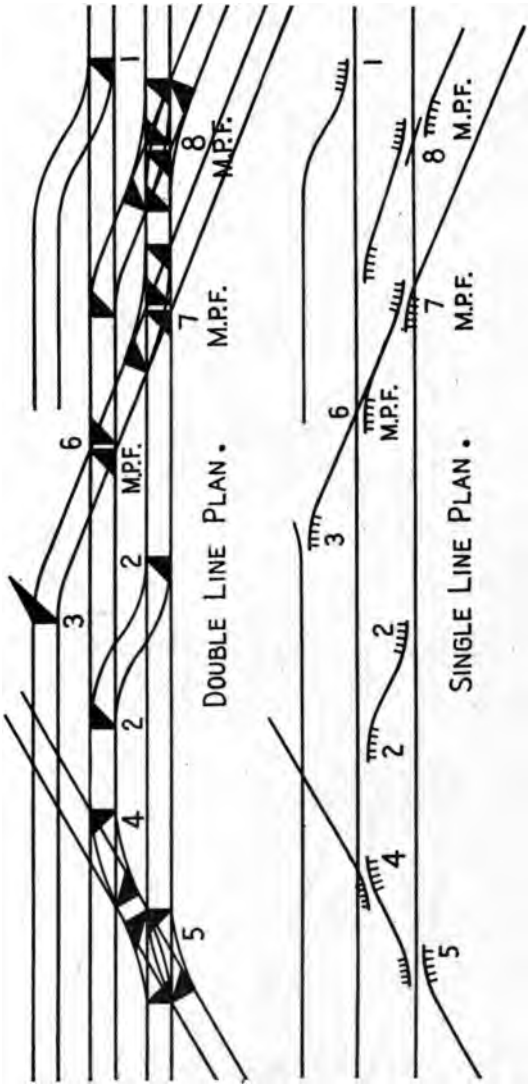
DERAIL—LIFTING RAIL TYPE—DERAILING.

DERAIL—LIFTING RAIL TYPE—NON-DERAILING.

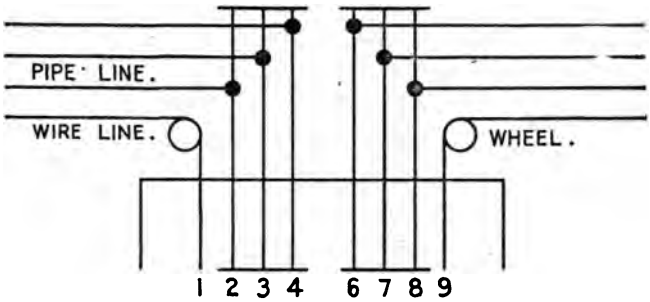
DERAIL—LIFTING BLOCK TYPE—DERAILING.

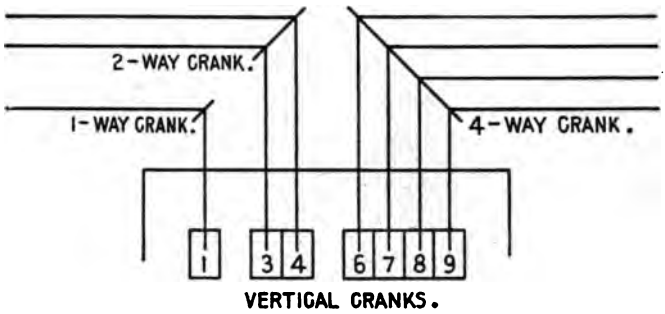
DERAIL—LIFTING BLOCK TYPE—NON-DERAILING.

INTERLOCKED SWITCHES AND DERAILS

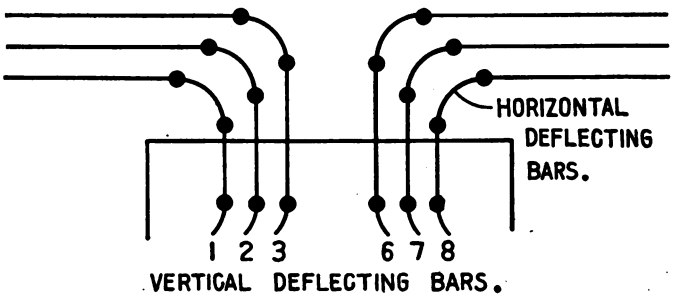


MECHANICAL INTERLOCKING

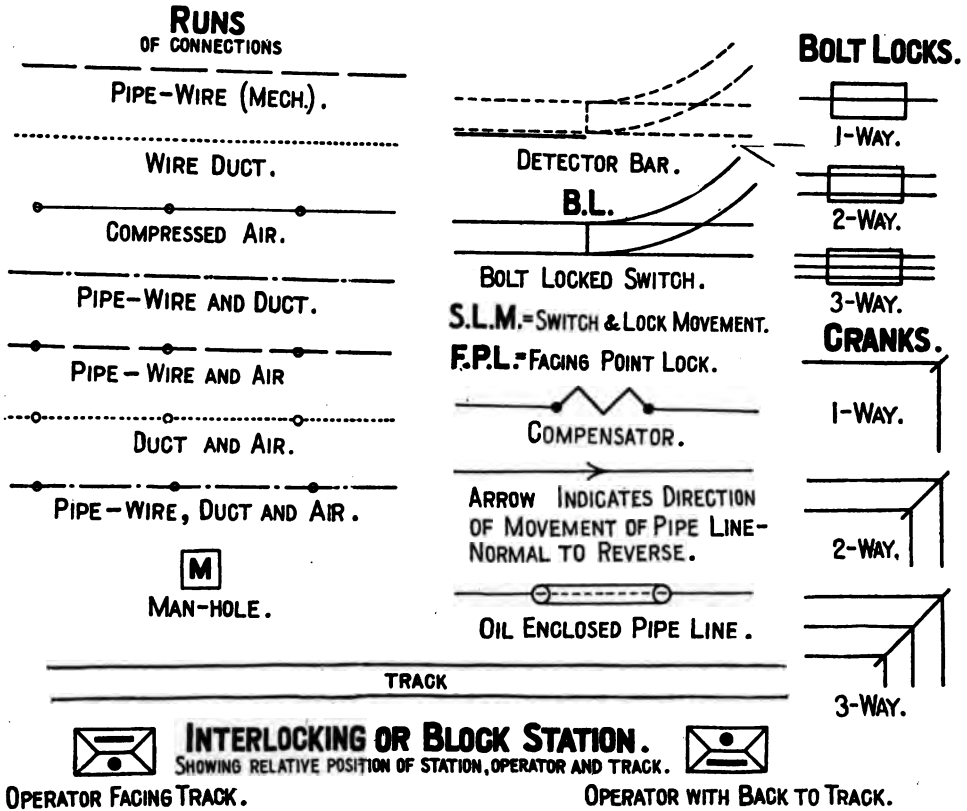




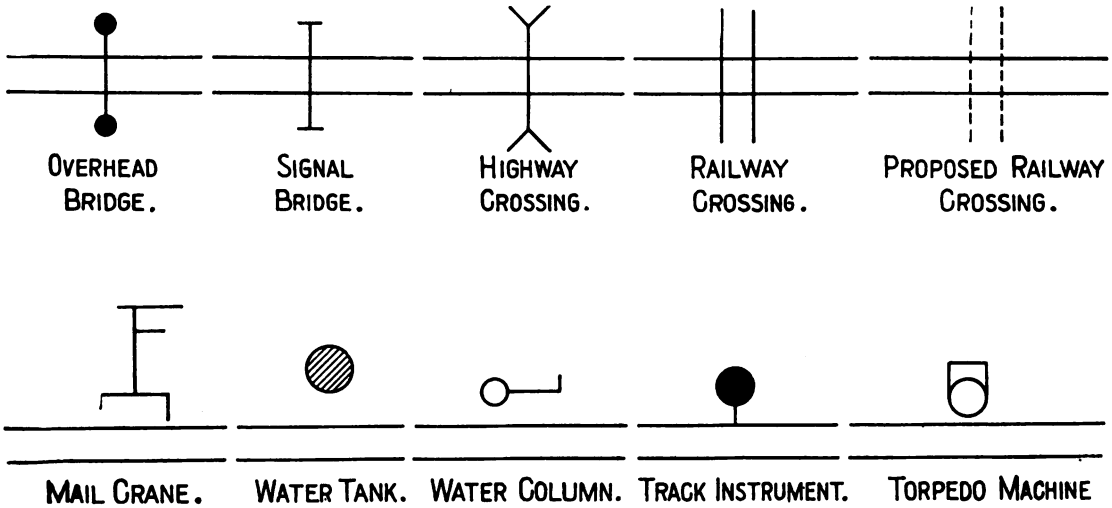
VERTICAL CRANKS.



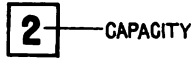
VERTICAL DEFLECTING BARS.


RUNS
OF CONNECTIONS
PIPE-WIRE (MECH.).
WIRE DUCT.
COMPRESSED AIR.
PIPE-WIRE AND DUCT.
PIPE-WIRE AND AIR
DUCT AND AIR.
PIPE-WIRE, DUCT AND AIR.
M
MAN-HOLE.
DETECTOR BAR.
B.L.
BOLT LOCKED SWITCH.
S.L.M.=SWITCH & LOCK MOVEMENT.
F.P.L.=FACING POINT LOCK.
COMPENSATOR.
ARROW INDICATES DIRECTION OF MOVEMENT OF PIPE LINE-NORMAL TO REVERSE.
OIL ENCLOSED PIPE LINE.
BOLT LOCKS.
1-WAY.
2-WAY.
3-WAY.
CRANKS.
1-WAY.
2-WAY.
3-WAY.
TRACK
INTERLOCKING OR BLOCK STATION.
SHOWING RELATIVE POSITION OF STATION, OPERATOR AND TRACK.
OPERATOR FACING TRACK.
OPERATOR WITH BACK TO TRACK.

ROADWAY APPLIANCE SYMBOLS



ROADWAY APPLIANCE SYMBOLS

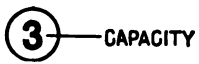


RELAY BOX.

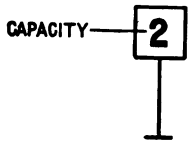
JUNCTION BOX.

TERMINAL BOX.

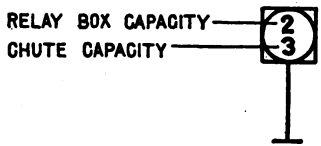
LIGHTNING ARRESTER BOX.



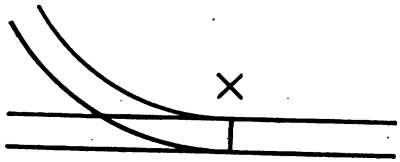
BATTERY CHUTE.



RELAY BOX AND POST.



BATTERY CHUTE, RELAY BOX AND POST COMBINED.

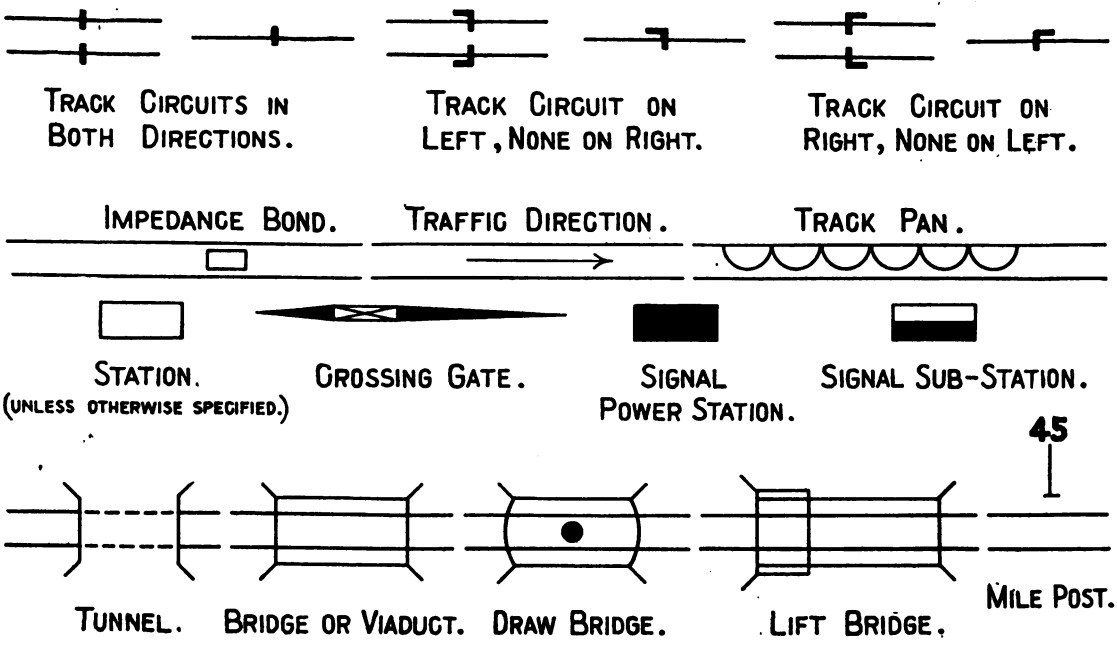


SWITCH BOX LOCATION.

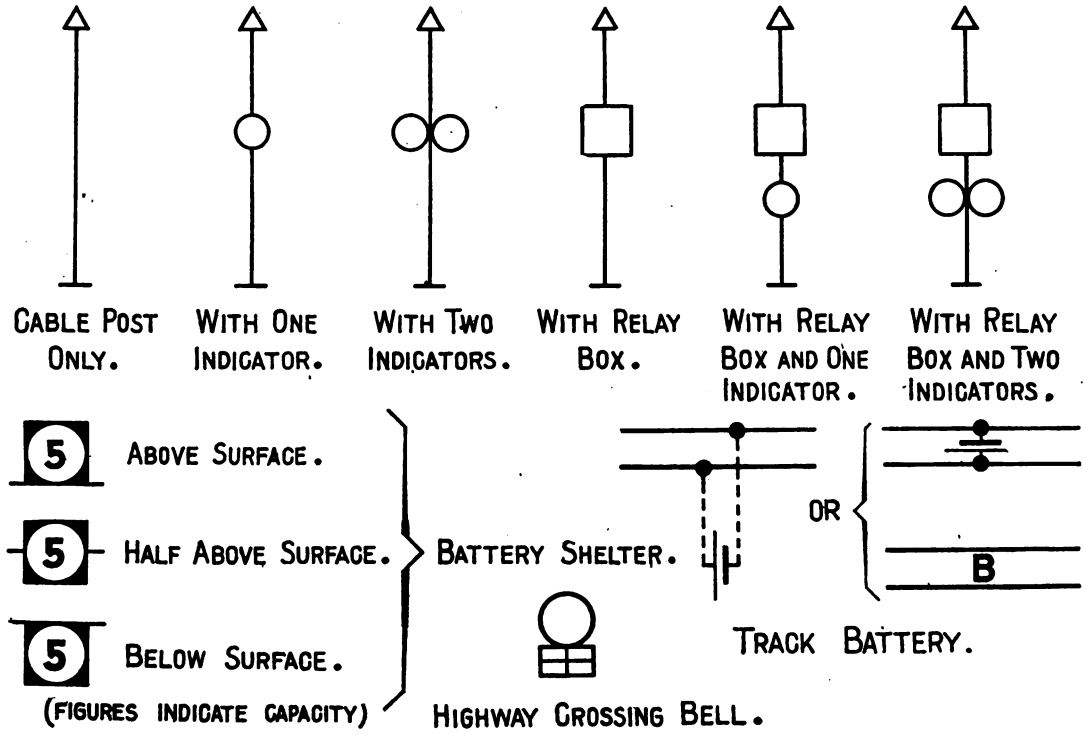
SWITCH INDICATOR.

SWITCH INDICATOR AND SWITCH BOX.

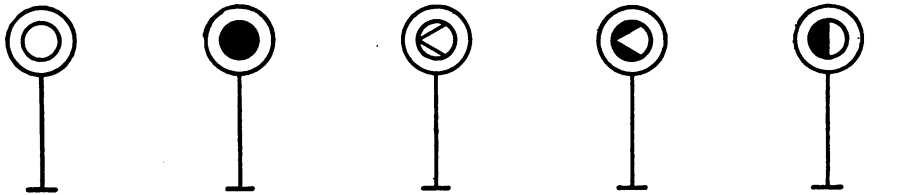
ROADWAY APPLIANCE SYMBOLS



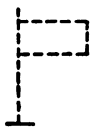
ROADWAY APPLIANCE SYMBOLS



SPECIAL SYMBOLS

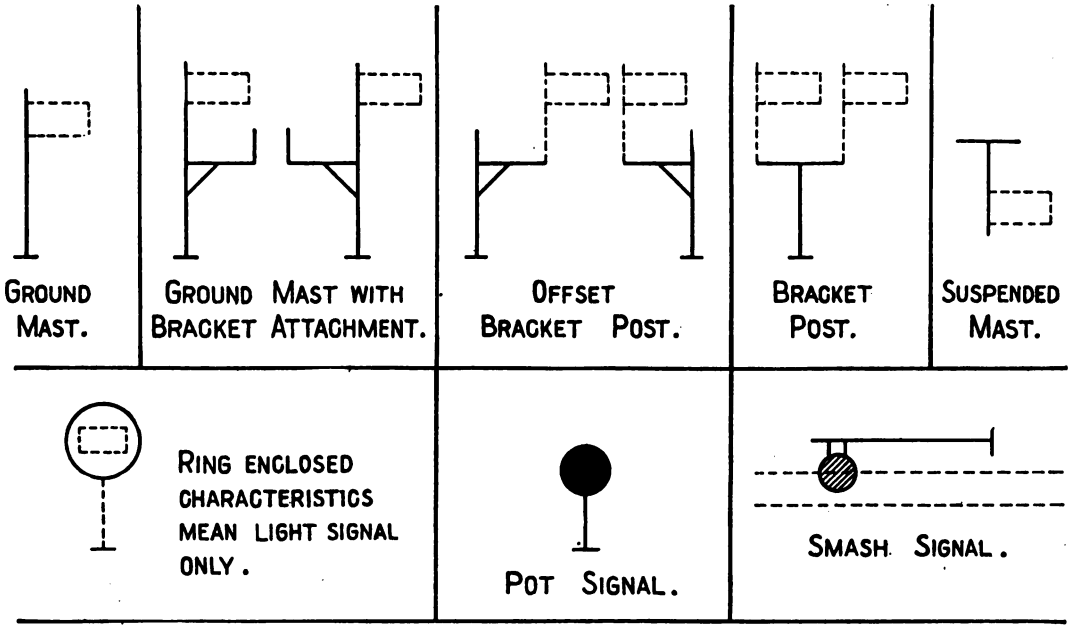


PRESENT SIGNAL TO BE REMOVED.

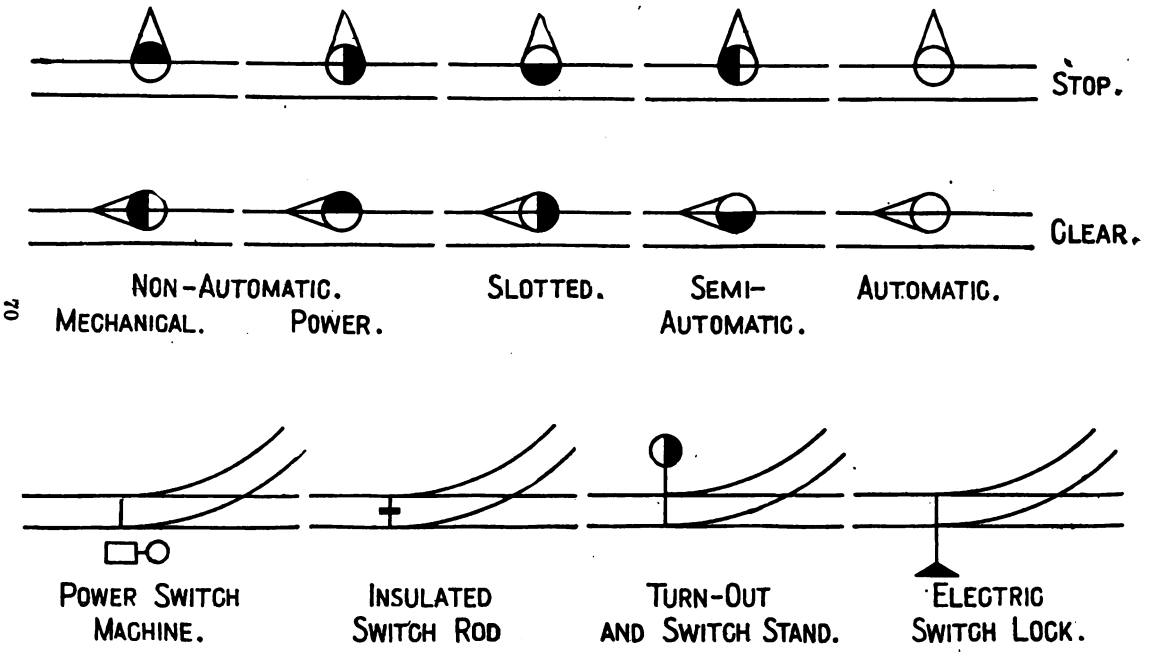


PRESENT SIGNAL TO REMAIN.

SPECIAL SYMBOLS



SPECIAL SYMBOLS



SIGNAL ASPECTS AND INDICATIONS

When plans or layouts of block signals or interlocking signals are made upon standard drawings, the standard symbols shown are used to cover all the different types of signal apparatus.

As signalmen are required to read these plans, it is necessary for them to know, and, if possible, to know at glance, just what each symbol means.

CHAPTER IV

THE TRACK CIRCUIT

PRACTICALLY all the automatic block signaling in this country is operated through the track circuit, which is built upon a very simple principle, but yet is responsible for the present high development of the art of signaling.

The purpose of the track circuit and track relay is to open and close signal or other circuits, the latter having much greater strength.

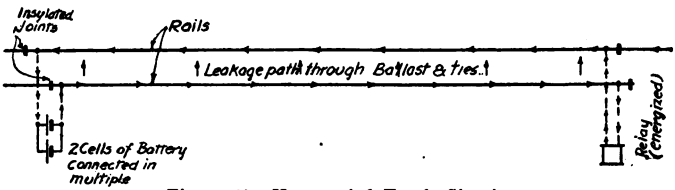


Figure 17—Unoccupied Track Circuit.

Definition—The track circuit consists of a section of track insulated at both ends from adjoining sections. The two track rails are utilized as the conductors for the current, and, with the track unoccupied, current flows from the positive side of the battery through one rail, then through the track relay and through the opposite rail, and then back to the battery, as indicated by arrows in the illustration.

Operation of Track Circuit—Anything which takes current away from the track relay allows the coils of the track relay to become de-energized and the pole pieces to become de-magnetized, and the relay armature then drops.

A train in a block "shunts" current away from the track relay. The current leaves the positive side of the battery, goes as far as the train, and then, instead of going on through the track circuit, follows the relatively low resistance through the wheels and axles

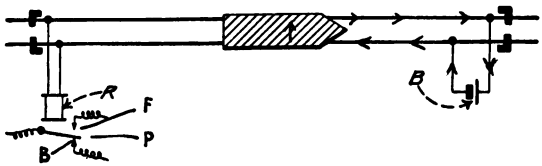


Figure 18—Train Moving Toward Battery.

of the train to the opposite rail, when it flows back to the battery. The wheels and axles of the train provide a much easier path for the current than the wire used in the relay coils. Therefore practically all the current will be drawn away from the relay, which as a result will become de-energized; and the armature will then be permitted to drop away from its contact, thus breaking the signal circuit.

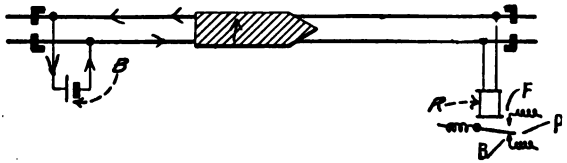


Figure 19—Train Moving Away from Battery.

Figures 18 and 19 show that the relay is deprived of current irrespective of at which end of the circuit the battery is located. Figure 18 shows the train going towards the battery, while Figure 19 shows the train going away from the battery. The effects

are the same. The relay is deprived of current in either case.

When the track is unoccupied by a train and is maintained in good condition, there will be a constant current flowing through the track relay. Thus there is a constant discharge of electricity and exhaustion of the battery whether or not the track is unoccupied by a train.

The coils of the track relay offer a relatively high resistance to the current, and therefore restrict its flow. When a train is in the block, the track battery is on closed circuit, and the discharge of current is higher because the resistance in the track circuit is greatly lowered, the high resistance of the relay coils being cut out and the low resistance of the wheels and axles substituted.

Track Circuit Current—To prevent an excessive waste of current through the track circuit, a current of low voltage is used. This means, however, that to transmit a given amount of energy a higher current must flow. Resistance to this flow means loss of power, and for this reason the rails and bonding of the track circuit must be as good conductors as possible.

There would be enough gaps in the track rail at the ordinary rail joint to stop the flow of the low voltage current used for track circuits. In order, then, to make the track circuit operate with this low voltage current, it is necessary to connect the ends of adjacent rails with bond wires, which give a much better contact than could be obtained through the rail joints.

Besides saving electric current when there are restricted leakage losses, the low voltage used in track circuits is of advantage in detecting broken rails. The

smaller the break necessary to prevent the flow of current, the more likely are small cracks in the rail to be discovered. Without the circuit being sensitive, leakage through the earth around the break might cause the relay to be energized.

Advantage of Low Voltage for Track Circuits—As indicated above, the principle upon which the track circuit works is the principle that an electric current will follow the path of least resistance. The wheels and axles of a single car or a complete train offer a very low resistance to a track current, and the current for this reason will follow this path and return to the battery. In every case this deprives the relay coils of current and allows the armature to drop and the signal to fall by gravity to the "stop" position. The resistance of track relays is usually 1.0, 4.0, 9.0 or 16.0 ohms, the latter for short track circuits at interlocking plants. The resistance of the wheels and axles of a car or train is exceedingly small as compared with the lowest of these, being somewhere in the neighborhood of one one-thousandth ohm.

It will be realized that the track circuit continues to indicate the presence of a train as long as a single pair of wheels remain upon the track section. It is in this way that track circuit control is so different from the forms of signal control which preceded it. With other types of control, the presence of a train was indicated only as it passed a single point, no further indication being given by the train itself until it passed the next control point.

Track Circuit Leakage—There is another reason a low voltage for track circuits is of advantage, and

that is that the insulation from rail to rail does not have to be as perfect as it would have to be if the voltage were high. Wood is considered to be a good insulator; yet when it is wet its insulating capacity is greatly reduced. There is some leakage from rail to rail through the ties of some track circuits, and where ties have been zinc treated, this leakage has sometimes become serious. The track ballast should be kept below the base of the rails to prevent current loss through it.

From these statements it is seen that the track circuit has very definite limitations. Its voltage cannot be materially increased without increasing the waste of current and the danger of shorts. On the other hand, the voltage cannot be decreased to the point where the current will not be strong enough to pick up the relay armature.

It will, of course, be realized that with any given voltage there is a limit to the length of the track through which current can be forced. Leakage of current through ballast or ties also limits the length of track circuits. Figure 20 shows a track circuit cut into two sections because it is too long to be operated by an ordinary track circuit current. The cut section is a method of getting around this difficulty without increasing the voltage of the track circuit and without spacing signals closer together.

The operation of track circuits has been greatly improved by the use of R. S. A. standard 500 A. H. potash cells with limiting resistance units and low-resistance relays—1.9 or 2.0 ohms.

The Track Relay—Relays have been used for many years in the telegraph department, and the track relay

is based upon the same principle as is the telegraph relay. Basically, the relay consists of an electro magnet and an armature. When a track circuit current is flowing through the coil of the electro magnet, the armature is attracted (raised) to the contacts. When the electro magnet is deprived of the track circuit current, the coil will be de-magnetized and the armature will be released and drop, the attraction having been removed.

Relays of many kinds have been developed in signaling, but they are all based upon the simple principle of the attraction of an electro magnet or upon the electrical forces set up by an electro magnet, no matter how complicated their design and functions may be.

The track circuit and its relay are used for controlling signals and other circuits, and the latter also function in the control of the signals. While the voltage of the track circuit is small, the voltage of any current which the armature of the track relay may open or close may be a good deal higher.

In Figure 20, a signal would be located at the right end of the drawing and another at the far left end, but none in the center. This makes it possible to put in two standard track circuits with the same number of battery cells and the same voltage as used in other track circuits, without placing the signals closer together.

Figures 21 and 22 illustrate clearly the action of the track relays on one of these cut sections, with a train in either one of the sections. In Figure 21, the track circuit at the right is not disturbed by the train at the left; but the relay at the extreme left is deprived

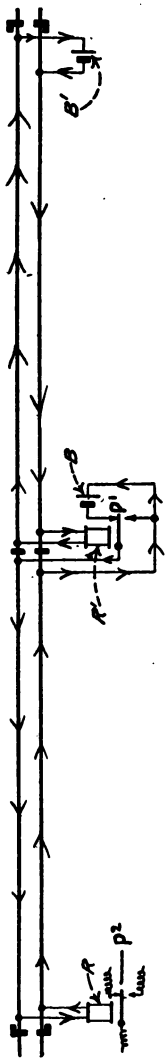


Figure 20—Cut Section Track Circuit Unoccupied.

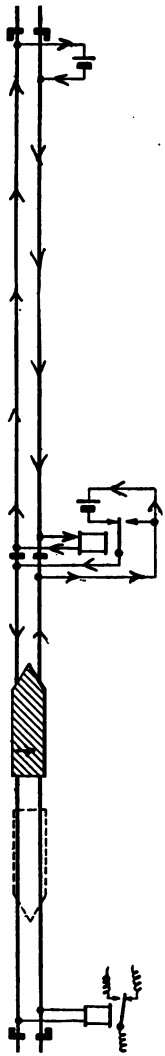


Figure 21—Cut Section Track Circuit Occupied.

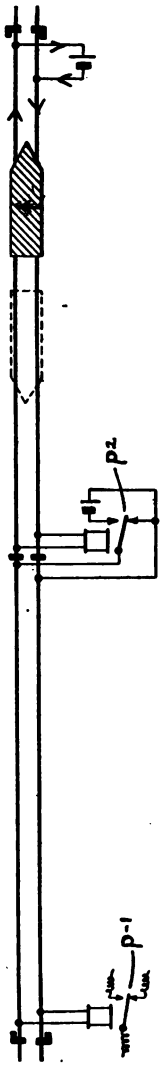


Figure 22—Train in Battery Section.

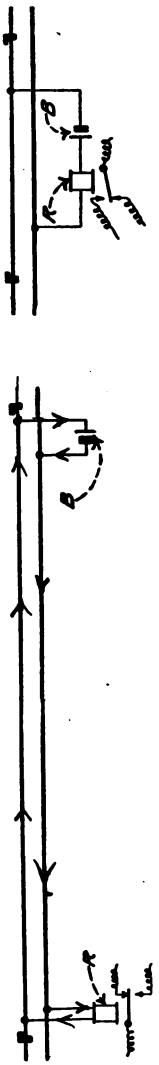


Figure 23—Single-Rail Track Circuits.

of current, thus permitting the signal at the extreme left to assume the "stop" position.

When a train has gone further and is entirely within the track section at the right, as in Figure 22, the track relay at the center is deprived of current, which allows its armature to drop. When this armature drops, the circuit at the left is also deprived of current because of a gap which has resulted in the circuit at P-2.

In the closed track circuits which we have shown, it is clear that a defect in the circuits will cause the signal to display the "stop" indication except in unusual conditions. This means that broken battery failures, either from exhaustion or from breakage, disconnected wires, crossed wires, poor connections, defective insulated joints, or a considerable decrease in the resistance of the ballast or ties, will produce the same effect upon a track relay as a train, because the track relay will not have sufficient current flowing through its coils to hold up the armature. And when any of these failures causes the track relay armature to drop, the signal assumes the "stop" position.

It is probable that every man who reads this knows the reason the track circuit and the track battery are not used actually to move the signals. As before explained, the electro motive force of the track battery must be kept low in order to give the greatest degree of safety and to prevent excessive waste of current. A higher electro motive force is necessary for operating signals and other units, and this is provided by a signal battery whose circuits are controlled by the track relay.

Single-Rail Track Circuits—Single-rail track circuits are so called because only one rail need be insulated at the ends of the track section. There are but two insulated joints for each track circuit instead of four, as required in the two-rail track circuit.

Single-rail circuits are not used extensively in D. C. installations for the simple reason that, while they reduce the cost somewhat, they also reduce the reliability of the signal indications. In case a single insulated joint breaks down, the current from one track circuit can penetrate to the next and interfere with the operation of the signal in that section.

Furthermore, detection of broken rails cannot be depended upon, because when a rail breaks in the common rail side, enough current might pass through a crossover to the opposite track, through the common rail of that track to another crossover and then back to the battery, having traveled all the way around a break by the crossover through a parallel track.

This latter failure, while it requires a combination of conditions which would not occur often, is to some extent a false clear failure, which all signalmen know should be avoided.

The only extensive use of single-rail track circuits is in alternating current installations where their maximum length is about 1,500 feet.

Polarized Track Circuits—The attraction of a magnetized substance by a positive current and the repulsion of the same substance by a negative current have been taken advantage of in signaling through the development of the polarized relay, in which the

polarized armature moves one way when the current is passing through the relay coil in one direction, and in the opposite way when the direction of the current in the coil is reversed.

With a polarized relay, the track circuit can be made to operate a signal to one indication when the current is positive and to another indication when the current is negative.

The use of polarized track circuits makes it possible to save a considerable length of line wire in the control of distant signals. The movement of the home signal blade operates a pole changer. In one position the pole changer causes the current to go through the track circuit in one direction, and in its other position it reverses the direction of the current.

Polarized Relay—The polarized relay is constructed like the ordinary track relay, but has a polarized armature which is attracted to one of the poles, depending upon the direction in which the current is flowing.

All polarized relays have a neutral as well as a polarized armature, and control circuits are broken through both neutral and polarized contacts.

The ordinary or neutral armature is attracted to the coil and always moves in the same direction when there is current in the relay, irrespective of the direction in which the current is flowing. The polarized armature, however, moves in one direction (to the right, for instance) when the current is flowing in one direction, and moves in the opposite direction (to the left) when the direction of the current is reversed.

As shown in Figure 24, when the signal arm is in the "proceed" position, the polarized armature will

take the position shown and will thus close the circuits of the distant signal, allowing it also to assume the "proceed" position. The arrows indicate the direction of the current.

When the pole changer is in the position shown in Figure 25, the polarized armature will be reversed

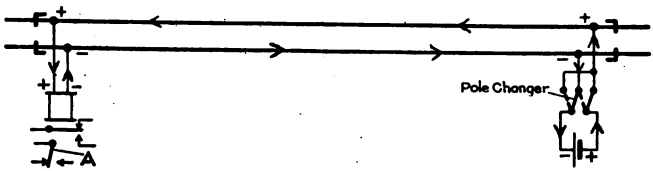


Figure 24—Polarized Track Circuit.

and will thus break the distant signal circuit (at X) and allow the signal to come to the "stop" position.

It should be understood that, while shown at the battery in Figure 25, the pole changer is located on the home signal at "Y," and operates the track circuit at "X." This is how the polarized track circuit is used to control the position of the distant indication

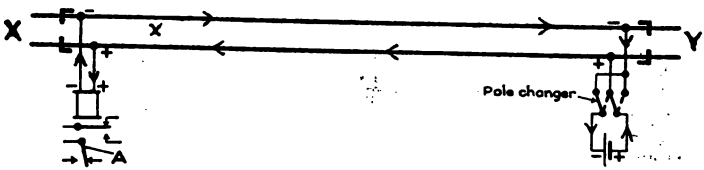


Figure 25—Polarized Track Circuit—Current Reversed.

without line wires from the home signal to the distant signal.

In the absence of a current, the polarized armature is retained in one position. In order to reverse the position of the polarized armature, therefore, it is evident that there must be no train in the block, for current otherwise will be shorted out of the relay.

Hence the position of the polarized armature will not be reversed when a train is in the block, even though the pole changer is reversed; but this is not of any consequence, since all circuits for the signal are broken through neutral contacts which will be open with a train in the block.

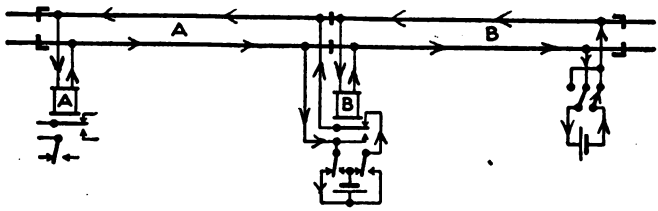


Figure 26—Cut Section Polarized Track Circuit.

Polarized track circuits may be cut into two sections similar to the ordinary track circuit. A circuit of this kind is illustrated in Figures 26 and 27. The arrows show the direction of the current, with the pole changers first in one position and then changed to the other. It will be noted that the direction of

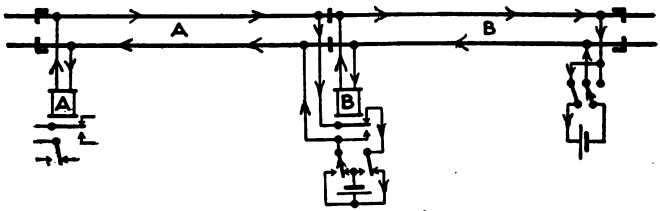


Figure 27—Cut Section Polarized Track Circuit—Current Reversed.

the current changes in both circuits "A" and "B" when the pole changer reverses.

Another method used for changing the polarity or direction of the current is to have two sets of batteries connected up to the circuit in such a way that

when the current is flowing from one battery, it is in one direction in the track circuit, and when it is flowing from the other battery, it is in the opposite direction. When the signal is in one position, the circuit controller connects up one set of battery, and when the signal changes its position, it connects up another set of battery.

Under this arrangement, one battery is always on open circuit; and in this way these batteries get some rest, which in the case of primary batteries is very desirable. This arrangement is somewhat more ex-

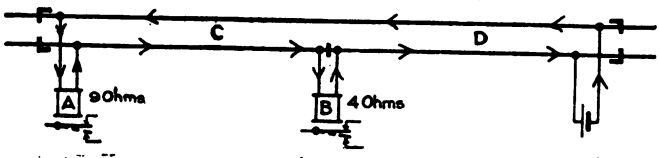


Figure 28.

pensive than the one where the connection of the same batteries is reversed.

Special Track Circuits—Sometimes it is necessary, or at least desirable, to extend the indication of one relay over a length of track which is controlled by another relay. In this case a circuit is used similar to Figure 28. One battery can supply this circuit, which is looped around an insulated joint in the middle and through the track relay. When the train is between the two relays, as indicated at "C," relay "A" is de-energized, but relay "B" remains energized, because the current continues to pass through relay "B" until it goes through the wheels and axles of the train. When, however, the train gets to position "D," both relays will be de-energized, and thus relay "A" will indicate the same as relay "B."

The reason for winding relay "B" with lower resistance (4 ohms) than relay "A" (9 ohms) is that it is nearer the battery and is subjected to less current loss than is relay "A."

Normally Open Track Circuit—The rules of the A. R. A. and other associations do not permit open circuits, the reasons for which are obvious.

Track Circuits and Switches—The carrying of track circuits through switches of course requires some special arrangements; otherwise the circuits would be shorted from rail to rail and also might penetrate to other circuits and operate them.

There are, in general, two methods of wiring switches—series wiring and shunt wiring. In the method of wiring used on the Chicago & North Western (Figure 29), the idea is to put all the rails possible into series and thus increase the broken rail protection afforded by the track circuit. Other arrangements of insulating sidings and crossovers are shown in Figures 30 and 31.

Figures 32 and 33 illustrate protection for switches in main lines and derails on sidings. In one case the siding rails are in shunt, and in the other they are in series.

Track Circuit Maintenance—Signalmen are quite familiar with the more common track circuit troubles, which include battery and relay troubles, defective connections, defective insulated joints, excessive ballast or tie leakage, and a large number of other unusual and rare cases—such as, for instance, one which we saw recently marked: "Sleigh driven across the track at crossing." Foreign current or poor wheel

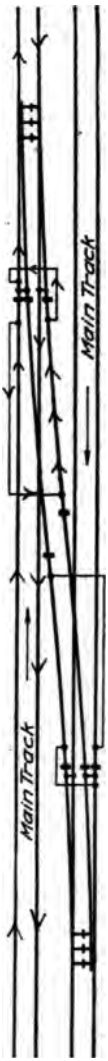


Figure 29—Series Switch Wiring.

Figure 30—Shunt Switch Wiring.

Figure 31—Shunt Switch Wiring.

Figure 32—Derail Protection.

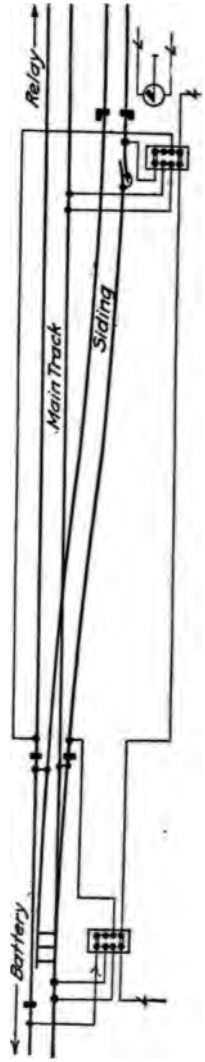


Figure 33—Derail Protection—Series Wiring.

contact are sometimes responsible for false "clears" while a train is in the block section.

Much of the apparatus and material in the track circuit is affected greatly by temperature changes. Tightening of the track by expansion may eventually cause trouble with the insulated joints, as when the track gets so tight that it squeezes the insulation, thus allowing current to flow through from one rail to another. Sometimes a rail head will be so pounded or battered at an insulated joint that it bridges the gap. Defects such as these, of course, will be noticed when the normal force of maintainers is employed; but when working with reduced forces, uncommon defects such as these are likely to be overlooked because of lack of time for careful inspection.

Temperature has some effect upon the operation of relays. When the temperature of the relay increases, a higher voltage is required to pick up the armature, and under lower temperature, the armature will pick up with lower voltage. Under these circumstances, it is evident that a relay is more likely in cold weather than in hot weather to fail to release because of an imperfect shunt, for a lower voltage will hold the relay armature up.

The greatest variation in track circuit operation, especially with low-ballast resistance, is between dry and wet weather conditions.

Union Switch and Signal Company's Double-Track Signals.

CHAPTER V

SIGNAL SYSTEMS

IN the preceding chapter on track circuits, some idea was given of the various types of signaling which are used on American railroads.

The signal circuits necessary to take care of some methods of signaling would be simple enough were it not for switch circuit controllers, switch indicators, etc.

The definitions of the various signal indications mentioned in this chapter are given in Chapter I, so no further description need be given here.

Two-Position Two-Arm Signals, Wireless—In Figure 34 is shown a simple wiring diagram for two-position two-arm signals, in which the distant signal is controlled through a polarized relay.

At signal location No. 1, it will be noted, by following out the circuits, starting at the positive side of the battery (the arrows indicate the direction of current flow), that electric circuits are closed through both the upper and the lower arms of the signal. With these circuits closed, both of the signals will indicate "proceed."

The lower arm in signal No. 1 is controlled by the direction of the current through the polarized relay; and the direction of current is governed by the circuit controllers located on the *top arm* of signal No. 2. The upper arm of signal No. 2 is in the "proceed" position, and therefore the distant signal arm on signal No. 1 should be as shown—in the "proceed" position. To

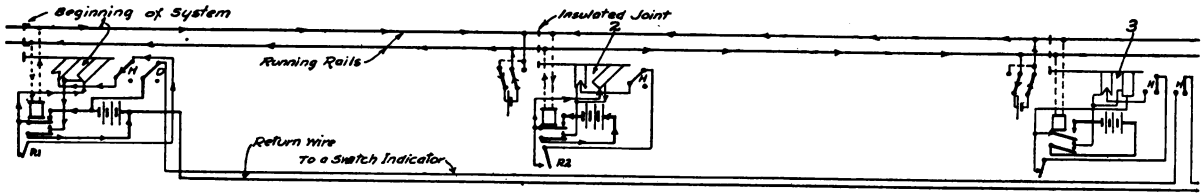


Figure 34—Two-Position Two-Arm Signals, Wireless.

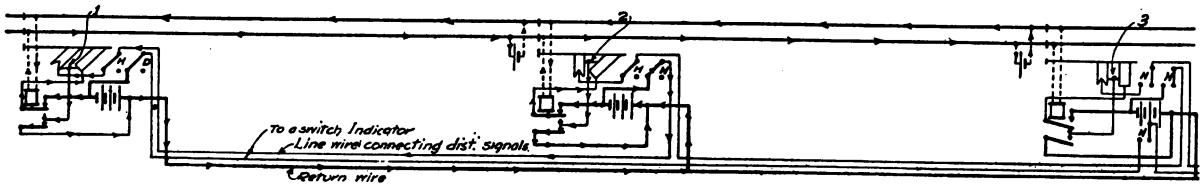


Figure 35—Two-Position Two-Arm Signals, Line Wire.

find the direction of the polarized circuit current, we start at the positive terminal of the track battery near signal No. 2. The arrows show the direction of the current in the track circuit.

In signal No. 2 we have the upper arm at "proceed," indicating that one block in advance is clear, and the lower arm in the horizontal position, indicating that home signal No. 3 in advance is at "stop." Under these conditions, the upper arm of signal No. 2 will be on closed circuit, but the lower arm will be on open circuit and will thus be allowed to assume the horizontal position. By following the arrows on the signal circuits at signal No. 2, it is easy to see that the top arm is getting current, but that the lower arm is disconnected from the battery by polarized armature "P-2" and is therefore not getting current. Since the lower arm of signal No. 2 is in the horizontal position and the lower arm of signal No. 1 is in the "proceed" position, we would naturally expect to find that the current in the track circuit governing signal No. 2 and in the track circuit governing signal No. 1 is flowing in reverse directions.

The circuit controllers located on signal No. 3 govern the indication of the lower arm of signal No. 2; and by starting at the battery at signal No. 3 and following the direction of the current by the arrows; we discover that the current is flowing in the opposite direction from that in signal No. 1. Also note that the direction of the circuit controller at No. 3 is the reverse of that at No. 2. This should make the position of polarized armature "P-2" directly opposite that of polarized armature "P-1" of signal No. 1. Reference to the diagram will show that this is the case, "P-2" being de-

flected to the right, having broken contact, and "P-1" being deflected to the left, having made contact.

Two-Position Two-Arm Signals, Line Wire—Figure 35 shows two-position two-arm signals similar to those in Figure 34, except that in these the distant signal is controlled through a line wire. It will also be noted that there are three line wires in Figure 35, whereas there are only two in Figure 34.

By following the arrows at signal location No. 1 in Figure 35, it will be seen that the signal circuit for the top arm is closed, this arm thus being allowed to assume the "proceed" indication.

To follow the circuit controlling the lower arm of signal No. 1, we run along the line wire to the location of signal No. 2; and we find that the circuit is closed from the battery at signal No. 2 and that current is passing through the line wire, as indicated by the arrows. This circuit runs through the lower arm of the signal and from there through the lower armature of the track relay, and finally through the "common" wire, returning through this to the battery at signal location No. 2.

The distant or lower arm of signal No. 2 is in the horizontal position, while the lower arm of signal No. 1 is in the "proceed" position. But it will be noted that the direction of the current in the track circuit is the same in both of them; whereas in the polarized system shown in Figure 34, the current in track circuits No. 1 and No. 2 is flowing in opposite directions.

In signal No. 2 of Figure 35 we observe that the upper arm is in the "proceed" position, but that the lower arm is in the horizontal position. Therefore

we may expect to discover that the circuit through the lower arm is broken and that the circuit through the upper arm is closed, the signal thus having been permitted to operate to the "proceed" position. To check this up, start at the battery and follow the arrows. We can determine the condition of the circuits in the lower arm by following the line wire. Start at the signal battery at signal No. 3, remembering that the position of the upper blade of signal No. 3 governs the indication of the lower blade in signal No. 2.

At signal location No. 3 we find that the line wire is cut off from current from the battery by a break in the circuit, the track relay being open. The lower arm of signal No. 2 therefore operates to the "stop" position because it is deprived of current.

At signal location No. 3, both signal arms are at "stop," and hence both signal arm circuits should be open, with no current flowing through them.

We can easily see that this is the case by looking at the top contact of the track relay at signal No. 3, through which all current from the battery must pass. Since the armature has dropped away and broken the front contact, no current can pass to either signal arm. Being deprived of current, both signal arms will assume the "stop" position, as shown.

Home and Distant on Separate Poles, Wireless—Figure 36 shows an installation of home and distant signals on separate poles, the signals operating in two positions in the lower quadrant, with polarized control of the distant indication.

In signal No. 1 the distant signal is at the "proceed" indication, so we would expect to find all signal cir-

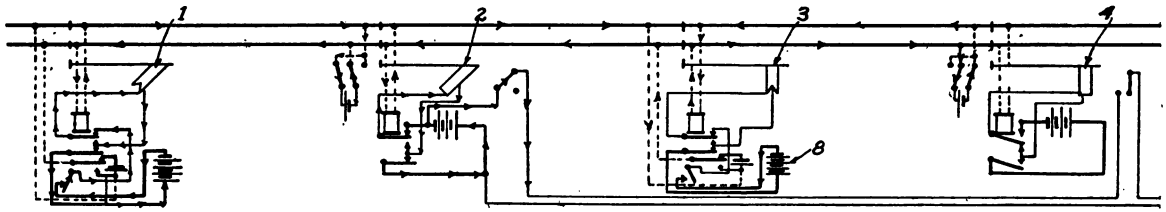


Figure 36—Home and Distant Signals on Separate Poles, Wireless.

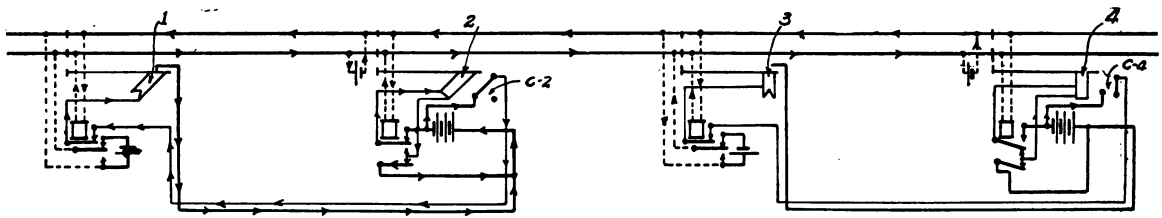


Figure 37—Home and Distant Signals on Separate Poles, Line Wire.

cuits closed at this point. If we follow the arrows, starting at the battery, we will discover that this is the case. The signal current goes through the closed polarized armature contact of the relay, then up through the closed neutral armature contact to the signal, and then back through a second neutral armature contact into the battery. The signal circuit will be broken either by the dropping of the neutral armature or by the moving of the polarized armature toward the right. That is, the signal circuit will be broken by a lack of current or by a reversal of current in the track circuit.

In signal No. 2 we have a home signal in the "clear" position, which indicates that the signal circuit at this signal is closed. It will be observed that there is no polarized armature at this home signal, its indication being controlled by the action of distant signal No. 3. To check this control, start at the track battery (at signal No. 3) and follow the arrows. We find a closed circuit through the track, current passing from the battery through the front contact of the track relay at signal No. 3, through the track circuit at signal No. 2, through the track relay at signal No. 2, and back through the track rails to the battery.

We note in this layout that although distant signal No. 3 is in the "stop" position, it has not broken track circuit for signal No. 2, a home signal, and allowed it to operate to the "stop" position. The reason for this is that no train is in track circuit No. 3, the train being in track circuit No. 4. Therefore signal No. 3 should be at "stop" and home signal No. 2 should indicate "proceed," as the train is in the second block in advance of the home signal.

No. 4 is a home signal at "stop," indicating that the signal circuit is broken. We see that this signal circuit is made or broken by the front contact of the track relay; and as this front contact is open, the passage of current is prevented.

Home and Distant on Separate Poles, Line Wire—Figure 37 shows lower-quadrant two-position signals, home and distant signals on separate masts, the distant indication control of which is through a line wire. We also find something we have not run across before in our study: that is, we find that the signal battery at signal No. 2 furnishes the current which operates signal No. 1. This can be done economically through a line wire in a direct current installation where the signals are close together. To trace the circuit which is holding signal No. 1 in the "proceed" position, we start at the battery at signal No. 2 and follow the arrows. We thus discover that the circuit is complete through the circuit breaker on the signal, through the line wire, through the closed front contact of the track relay, through the signal, and back to the battery at signal No. 2 through a return line wire.

Signal No. 2 is in the "proceed" position also, and therefore we would expect to find the circuits at this signal closed too. In checking this up, we find that the current passes through the closed front contact of the track relay at signal No. 2 to the signal, and then back through another closed front contact of the relay to the battery.

As signal No. 3, a distant signal, is in the "stop" position, we look for a broken circuit. Signal No. 3, like signal No. 1, obtains its current from battery at

the home signal in advance—in this case from signal No. 4. In tracing the circuit from the battery at signal No. 4 through the line wire and back to signal No. 3, we discover a break at circuit controller "C-4," which cuts off all the energy from the line wire and allows signal No. 3 to operate to the "stop" position.

It will be noted at signal No. 3, however, that the track circuit is completed, and that therefore the signal would assume the "clear" position if it were not prevented from so doing by the distant control from signal No. 4. In order that signal No. 3 may operate to "proceed," *both* the track circuit and the distant (line wire) circuit must be closed.

Two-Position Signals with Overlap, Polarized—In Figure 38 we find that signal No. 1 is at the "proceed" indication. This would seem to point to a closed signal circuit, which we find in following the arrows. We start from the battery and go through the closed front contact of the track relay to the signal, and then back through another closed front contact of the relay to the battery. This track circuit (1-B) is not polarized.

The distant indication of signal No. 1 is controlled through the track circuit, which is opened or closed by a contact of the relay at signal No. 2. Starting at the track battery at signal No. 2 and following the arrows, we trace this circuit through the front contact of the track relay at signal No. 2, through track circuit "1-B," through relay "1-B," and back through the opposite track rail to the battery. As the relay at "1-B" is energized, current from the track battery

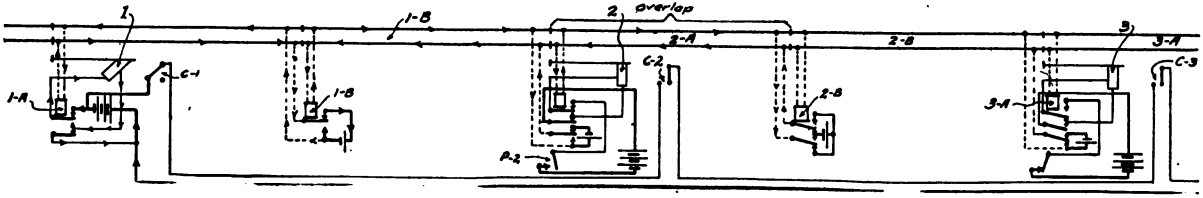


Figure 38—Two-Position Signals with Overlap, Polarized.

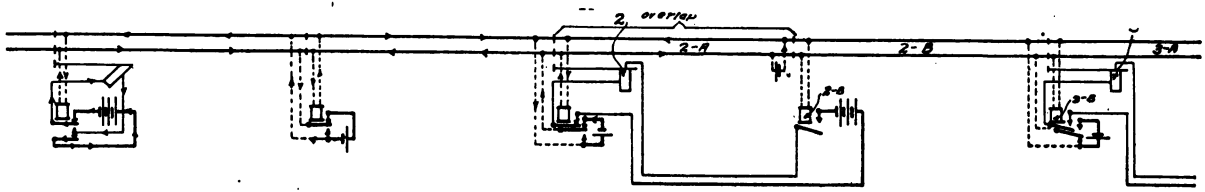


Figure 39—Two-Position Signals with Overlap, Line Wire.

at "1-B" is allowed to go through the circuit to the track rails, then through the rails to the relay at "1-A," and then through the closed front contact of the track relay at "1-B" back to the battery. Thus both track circuit "1-A" and track circuit "1-B" are closed and signal No. 1 indicates "proceed." The breaking of track circuit "1-A" causes the armature at "1-A" to break the signal circuit; and the breaking of track circuit "1-B" allows the relay at "1-B" to open, which breaks circuit "1-A" and opens the relay at "1-A," thus causing the signal to indicate "stop."

Signal No. 2 is at the "stop" indication, and therefore we would expect to find the circuit through this signal broken or open. Starting at the battery on the circuit for signal No. 2, we note that the polarized armature through which current must pass has moved to the right and has broken contact, current thus being prevented from passing through the signal.

It will be observed that the circuit breakers at both "C-2" and "C-3" are open. The reason for this is that signals No. 2 and No. 3 are both in the "stop" position, which in either instance prevents the current from the signal in advance from operating the signal in the rear to the "caution" or "clear" position, as the case may be.

In signal No. 1 the distant signal circuit is broken; and if the signal were controlled entirely by this circuit, it would be at the "stop" indication. Signal No. 1, however, is held in the "proceed" position by the closed track circuit. Both the distant signal circuit and the track circuit at signal No. 1 must be broken at the same time if the signal is to show the "stop" indication.

Referring to the relay controlled by circuit "2-B," we note that this circuit may be opened either by a train on "2-B" or through relay "3-A" by a train on circuit "3-B." Relay "3-A" as well as relay "2-B" being open indicates that the train is in circuit "3-A." A train at circuit "3-A" thus sets signal No. 2, the second opposing signal ahead, at "stop."

If track circuit "2-B" were closed, the contacts of relay "2-B" would be raised, and this would change the direction of the current in track circuit "2-A."

By breaking the signal circuit through polarized contact "B-2," signal No. 2 is thus allowed to operate to its "stop" position. This cuts off all circuit from the signal, even though the neutral contacts of the relays are closed.

The train in track circuit "3-A" operates opposing signal No. 3 and also signal No. 2 to the "stop" position and thus gives the desired overlap protection.

Two-Position Signals with Overlap, Line Wire—Figure 39 shows two-position lower-quadrant automatic signals with overlap and distant indication controlled by line wire.

Signal No. 1 is in the "proceed" position and therefore its signal circuit should be closed. Since this is the case, the current is passing through the closed contact of the track relay to the signal, and through another closed contact of the relay back to the battery.

As signal No. 2 is at the "stop" indication, we would expect to find its circuit broken. We discover that it is broken at relay "2-B," in the cut section where the signal battery is located. The control of track relay "2-B" is through track circuit "2-B," which in turn

is controlled either by a train or by relay "3-B"—shown open. When relay "3-B" is open, it indicates that there is a train on track circuit "3-A." Signal No. 2 is deprived of current by the break in the line wire circuit at relay "2-B."

Signal No. 2 cannot operate to "proceed" unless track circuit "2-A" is closed at the same time the line wire circuit from battery at "2-B" is closed.

Signal No. 3 is also in the "stop" position; and we note that track relay No. 3 is not energized and its contacts are open, which would indicate that a train is on track circuit "3-A." When the front contact of relay No. 3 drops, it breaks track circuit "2-B." Relay "2-B" being deprived of current, its armature drops and breaks contact "2-B," this in turn breaking the line circuit through signal No. 2. Thus the train to the right of signal No. 3 will throw both signals No. 3 and No. 2 to the "stop" position and give overlap protection against opposing trains.

Three-Position Signals, Wireless—Figure 40 illustrates a three-position upper-quadrant signal system in which the distant indication is obtained through the operation of a polarized relay.

Signal No. 1 is shown in the "clear" position, which would indicate that all signal circuits governing this signal are closed. By following the arrows, starting at the battery at signal No. 1, we find that this circuit, which is the circuit governing the "stop" indication, is closed, the current leaving the positive side of the battery and going through the closed front contact of the track relay to the signal, and back through a second closed front contact of the track relay to the

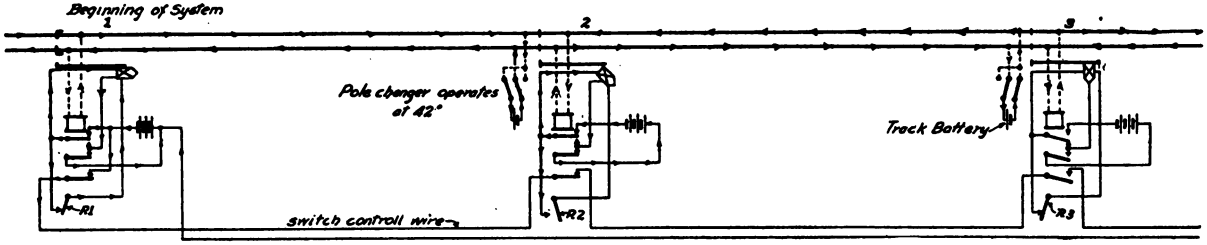


Figure 40—Three-Position Signals, Wireless.

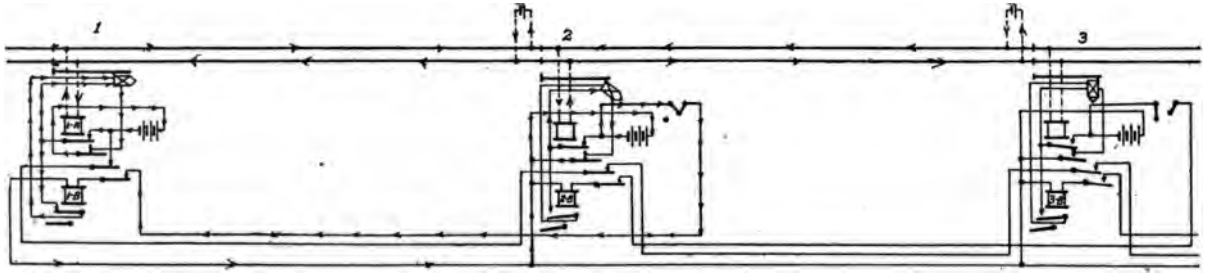


Figure 41—Three-Position Signals, Line Wire.

battery. This circuit being closed, the signal blade is allowed to operate from the "stop" position to the 45 degree or "caution" position.

Polarized contact "P-1" is closed, for it is deflected to the left against its contact; and this closes the "caution" signal circuit, as shown by the arrows, the current leaving the positive side of the battery and going through the closed front contact of the track relay, then down through the closed polarized contact to the signal, and then back through a second closed front contact of the track relay to the battery. Since both the signal circuits (that governing the "stop" indication and that governing the "caution" indication) go through a front contact of the track relay, a train in the home track circuit will break both signal circuits. A train in track circuit No. 2 will open polarized contact "P-1" and break only the signal circuit governing the "caution" indication.

Signal No. 2 being in the "caution" position, we would expect to find the home signal circuit closed and the distant signal circuit broken. We note that this is the case by following the arrows; and we also discover that the distant or "caution" signal circuit is broken, for the polarized contact is deflected to the right, away from its contact point.

Observe the arrows on track circuits No. 1 and No. 2, which show that the direction of the current in track circuit No. 1 is opposite to the direction of the current in track circuit No. 2. This difference in direction is accounted for by the fact that the position of the circuit controller on signal No. 3, governing the direction of the track circuit, is the reverse of that of the circuit controller on signal No. 2.

Signal No. 3 is in the "stop" position, and this would indicate that both the home signal circuit governing the "stop" indication and the distant or "caution" signal circuit governing the "caution" indication are broken. Both these circuits are broken because both the front contacts of the track circuit relay are broken, which cuts off all current from the signal battery.

Three-Position Signals, Line Wire—Figure 41 illustrates a three-position upper-quadrant signal system in which the distant signal control is given through line wire.

As signal No. 1 is in the "clear" position, all the signal circuits should be closed. We find this to be the case, the current for the "stop" indication leaving the signal battery and going through a front contact of the track relay to the signal, and back through a second closed front contact of the track relay to the battery.

The current for the distant or "caution" indication starts from the signal battery at signal No. 2 and goes through the closed circuit breaker on signal No. 2, through the line wire to signal No. 1, through a closed front contact of the track circuit relay and through relay "1-B," thus energizing relay "1-B" and closing the front contacts of relay "1-B." Another circuit at signal No. 1—the "caution" or distant signal indication circuit—is thus closed. This circuit leaves the positive side of the battery and goes through the closed front contact of track relay "1-A," then down through the closed front contact of relay "1-B" to the signal, and then back through a second closed front contact of relay "1-A" to the battery.

Signal No. 2 being in the "caution" position, it

would indicate that the circuit governing the "stop" indication is closed. The arrows show that that is so, the current leaving the positive side of the battery and going through the closed front contact of the track circuit relay to the signal, and back through a second closed front contact of the track relay to the battery. This circuit is in the same condition as the signal circuit governing the "stop" indication at signal No. 1.

In checking up the distant signal circuit which governs the "caution" indication of signal No. 2, we start at the signal battery at signal No. 3; but we discover that this circuit is broken by the circuit breaker on signal No. 3, so that no current can get to the line control wire running to signal No. 2. This allows the armature of relay "2-B" to drop, because relay "2-B" is deprived of current through the line wire; and the signal circuit from the battery at signal No. 2, which formerly went through the closed front contacts of relay "2-B," is thus broken.

Signal No. 3 is in the "stop" position, and therefore both the local signal circuits at signal No. 3 should be broken. We find this to be the case, since both the track relay front contacts and also the front contacts of relay "3-B" are broken. The signal is thus deprived of current through either of its two signal circuits.

These various signal systems are given in their simplest form in this chapter to afford a general idea only of the principles underlying signals as used today on American railroads. There are many modifications and additions to these systems, due to crossovers, highway crossing signals, interlocking plants,

etc.; but if the general plan of following out each separate circuit is pursued, it is possible to read very complicated plans.

The above descriptions apply mainly to double-track signal systems, although the overlap scheme shown has been used upon single-track lines.

The several classifications of double-track signaling are as follows:

(a) Two or three position.
(b) Upper or lower quadrant.
(c) Polarized or neutral track relays (D. C.).
(d) Two or three-position track relays (A. C.).
(e) A. C. or D. C. system.
(f) Steam or electric traction.

Absolute Permissive Block Signaling—Prior to the development of the A. P. B. signal system, single-track signaling was not highly considered, for in order to provide adequate safety for opposing movements, there was a considerable loss in facility for following movements. In other words, all that could be secured from the old systems was safety. The requisites worked out in the A. P. B. system are (1) absolute protection between passing sidings for opposing movements, and (2) permissive signaling, as on double track for following movements.

An absolute signal is distinguished by—

(1) Square-end blade—red or yellow.

(2) White or black vertical stripe, respectively, for red or yellow blade.

(3) Vertical marker light.

A permissive signal is distinguished by—

(1) Pointed-end blade—red or yellow.

(2) White or black diagonal stripe, respectively, for red or yellow blade.

(3) Staggered marker light.

The simplest protection against head-on collisions on single track is the opposing overlap, in which the control of the signal is carried beyond the next signal in advance, as in Figures 38 and 39. As soon as a train reaches the insulated joints at the left of Figure 38, it will operate signal No. 1 to the "stop" position. Likewise, when a train coming from the right in Figure 38 passes the insulated joints at signal No. 3, that signal will be operated to the "stop" position.

The overlap does not enter into the absolute permissive block system, the main idea of which is selecting the direction of traffic by means of the stick relay circuit. It is not possible, in this system, for opposing trains to enter the same block unless one train disregards signal indications, and also time-table rules and orders.

In the A. P. B. system, the control arrangement is such that the leaving signal at each siding controls all the opposing signals up to the next siding. The leaving signals at a siding are absolute signals. Unless the leaving signal is at "proceed," or "proceed with caution," the engineman is not allowed by rule to pass it. He must wait until the signal clears, communicate with the dispatcher, or, after waiting a certain time, proceed under protection of the flagman as prescribed by rules.

To explain this more in detail, we refer to Figure "A." When signal No. 2 at the left comes to the "stop" indication as a train leaves the siding at "X," the control operating through signal No. 2 will set

signal No. 3, at the siding in advance, at the "stop" indication. This is illustrated by the control line, which, it will be noted, runs from signal No. 2 up past the insulated joints at No. 3 and thus operates signal No. 3. The opposing control of signal No. 3 likewise runs up to and through signal No. 2.

Figure "A".

When a train leaves siding "X," it operates signal No. 2 to the "stop" position and thus protects against following trains; and it also operates signal No. 3 to the "stop" position, in this way preventing opposing trains from leaving siding "Y." This arrangement therefore affords full protection against opposing movements.

It is not necessary in most cases to prevent trains from *following* a train which has left station "X." Hence, when a train going from left to right reaches signal No. 4, signal No. 2 should operate to the "caution" position, in order that a following train need not lose time in waiting for the train in advance to move on to the next siding.

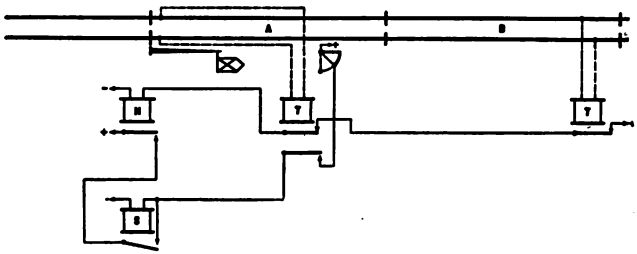
This is how the absolute permissive block system received its name. It gives absolute or "stop and stay" protection against the opposing movements up to the next siding, but gives permissive protection against following movements. That is, it allows a following train to operate in the same way as it would in the permissive signaling on double or multiple track.

When signal No. 3 is operated to the "stop" posi-

tion by a train leaving siding "X," signal No. 2 is also operated to the "stop" position, as are all other opposing intermediate signals such as signal No. 1. Thus, if a train should leave siding "Y" by mistake, overlooking the "stop" indication at signal No. 3, the train would find all signals indicating "stop."

Therefore, in absolute permissive signaling the control of the signal is variable and depends upon the direction of the traffic. A stick relay, marked "S" in Figure "B," is the means for providing this variable control. In this diagram, "H" is the control relay for the signal, "H" in turn being controlled by the two track relays "T," which are connected through track circuits "A" and "B."

Stick relay "S" supplies a medium through which the direction of traffic is determined. The relay is



"Figure "B".

energized during the time a train is moving a block in one direction, and it is de-energized when the train is moving in the other direction.

Examination of the diagram will show that the pick-up of the stick relay is through a back contact of the relay at track circuit "A" and a contact operated by the signal, this latter contact being closed from the 45 to the 90 degree position.

The Signal Dictionary says that a stick relay is "a relay of the ordinary type so connected that its armature closes a circuit through its own coil"—that is, there are two paths for the current.

The main point of the stick relay is that, after being picked up in the usual manner, it will "hold up" through its armature until the *holding* circuit is opened, even though the *pick-up* circuit is broken. Both the pick-up circuit and the holding circuit must be broken before the armature will release.

The holding circuit for the stick relay is through a front contact of the stick relay itself and a back contact of the signal control relay.

It will therefore be seen that when a train passes the signal, moving from left to right, it first causes the armature of circuit "A" to drop, and then the signal, as it falls, causes the pick-up circuit to be made. In other words, the falling signal closes a contact for a length of time sufficient to pick up the stick relay, and the stick relay will stay picked up as long as the signal control relay is de-energized. It should be noted that the contact operated by the signal can be closed at any part of the stroke, but that it must be open when the signal is at "stop," and be closed, after passing below the 45 degree position, for a period sufficient to allow the stick relay to pick up. The contact is closed, roughly, from 85 degrees to 47 degrees.

It will furthermore be observed that a train moving from right to left will not pick up the stick relay, for the de-energization of track circuit "B" will cause the signal to assume the "stop" position before the train reaches track circuit "A." Therefore the pick-up circuit will not be made at any time.

Thus we have a means of establishing the direction of traffic: a relay energized during the time a train is moving through a block in one direction, and de-energized when the train is moving in the other direction.

An application of this means of differentiating traffic direction is shown in Figure "C." Signal No. 4 controls to point "M"; and if we disregard wire "X," signal No. 2 will control to "M," as the control wire for signal No. 2 is broken through the control relay for signal No. 4. It will be noted that wire "X" feeds

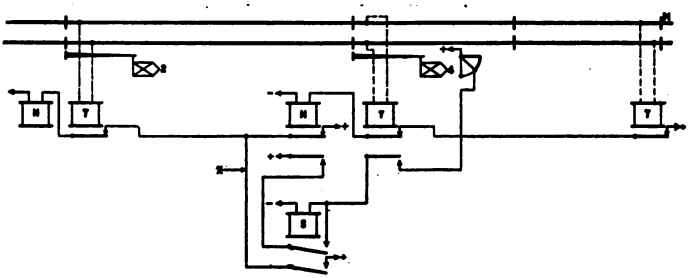


Figure "C".

energy to the control wire for signal No. 2 when the stick relay is picked up, even though the control relay for signal No. 4 is de-energized. Therefore, a train moving from left to right will allow signal No. 2 to clear as soon as it passes signal No. 4, for the stick relay will be picked up as long as the train is in the block of signal No. 4. But in the case of a train moving from right to left, both signal No. 2 and signal No. 4 will be operated to the "stop" position as soon as the train passes "M," the stick relay not picking up for this movement. In other words, signal No. 2 has

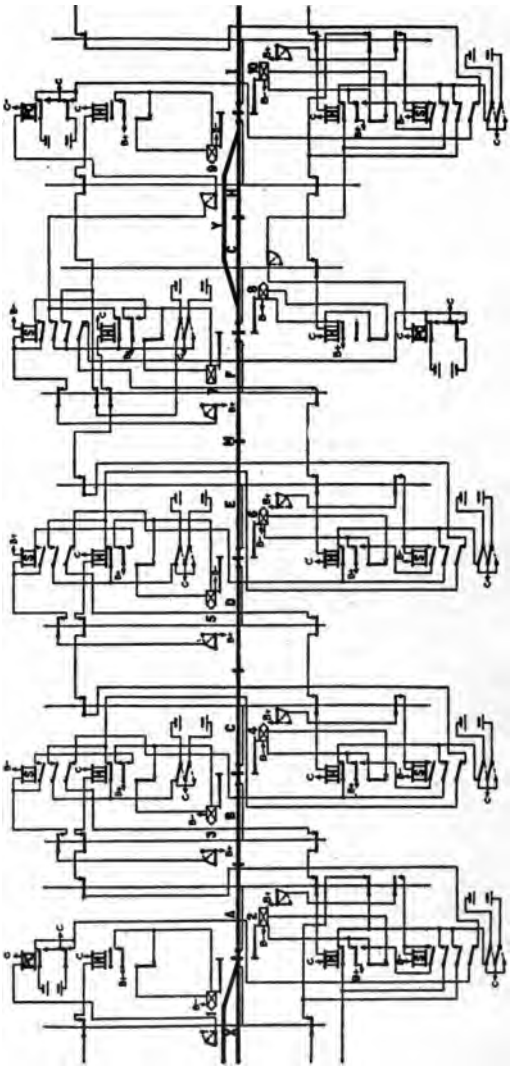


Figure "D".

an overlap for opposing movements, but not for following movements.

Figure "D" shows the arrangement of signals and circuits usually employed, it being understood that in practice modifications are made because of local conditions and general standards. For instance, siding arrangements and their relative positions vary. Some roads want polar line-circuits, while others insist upon neutral; some employ three-position signaling and others two-position; and some use one battery for line and motor control, while others use separate batteries.

Two simple sidings, "X" and "Y," with the usual entering and leaving signals at each end and with two pairs of intermediate signals, are shown in Diagram "D." However, it makes no difference whether the intermediate signals are in pairs or staggered except that, if there is only one intermediate signal for each direction, between sidings, the distance between should not be less than twice the safe braking distance.

It will be seen that the control wire for signal No. 2 is carried forward and broken through front contacts of the control and stick relays at signal No. 4. Likewise the control of signal No. 4 is carried forward to signal No. 6; but signal No. 6 only controls to signal No. 8, or to the end of the track block. Signals No. 7, No. 5 and No. 3 are controlled in exactly the same way as signals No. 2, No. 4 and No. 6.

Therefore, a train moving from right to left, upon passing signal No. 7, will cause signals No. 6, No. 4 and No. 2 to assume the "stop" position, for the stick relays at signals No. 4 and No. 6 will be de-energized. A long overlap is in this way provided for opposing

movements (to the next siding in each case); but these overlaps are cut off by the stick relays in the manner already explained.

Moreover, the siding signals have a varying control, depending upon direction. For example, signal No. 9 controls to "M" for opposing movements, but only to signal No. 7 for following movements.

One of the first questions brought up with regard to the absolute permissive block system described herein was as to what would happen if the stick relay at a signal were picked up improperly for any cause.

If this occurred, signal No. 2 would be at 45 degrees, even if an opposing train were between signal No. 4 and signal No. 7. To protect against such a condition, the control for signal No. 5 is broken through a back contact of the stick relay for signal No. 4. Thus, after a train has passed signal No. 4, moving from left to right, the stick relay for signal No. 4 must again drop before either signal No. 5 or signal No. 7 can clear for an opposing movement. When a train movement has established traffic in one direction with this system, the signals will not permit a reversal of traffic until the stick relays have been restored to normal, or to the de-energized position.

(a) It is well to remember that the object of the A. P. B. system is to permit the same facility of operation on single track between passing sidings as on double track.

(b) The *direction of traffic* is established by the train which first passes an absolute or leaving signal.

(c) Trains may then follow as if the main track were one of the two main tracks of a double-track line.

(d) All trains must pass out of the block between

sidings before the opposing signal will display a "proceed" indication (proceed or proceed with caution).

(e) A train entering from the opposite direction will in turn establish the opposite direction of traffic, and trains may then follow it with the same facility of operation as in the first case.

It should be understood that, as generally used, the absolute permissive block system for single track provides for the movement of trains in accordance with the method that is ordinarily followed in the time-table and train order operation, but that it adds to this the protection of block signals.

Thus the entrance of trains into any given block is usually covered by time-table or train orders. Trains which are given the right-of-way over a considerable stretch of track make only the usual time-table stops if not stopped by the signals. Other trains are kept on the sidings by train or time-table orders at the proper passing point.

The operation of trains which have the right-of-way over other trains is therefore not impeded by the absolute permissive block system.

Automatic signals do not relieve trainmen from the observance of the book of rules, time-table or train orders. However, as the train-dispatcher's orders are superior to time-table schedules and rules, he can frequently take advantage of the automatic block protection and considerably facilitate traffic.

Tonnage Signals—It is often necessary to locate automatic block signals on ascending grades where it is difficult or impossible to start a tonnage train if it is stopped by a signal.

Under the protection of the A. P. B. system, and

since movements up-grade are made at slow speed, there is no sacrifice of safety if trains are allowed to pass permissive stop signals at slow speed, but without stopping. This applies, of course, to following trains and not to opposing trains; and in a case of this kind there must be some indication to show the engineman that the train which is in the block ahead is not an opposing train.

The tonnage signal has been developed for this purpose. It consists of a secondary arm placed below the top arm of the signal. The upper arm operates in three positions—displays the "stop," "caution" and "proceed" indications—and is controlled in the same way as other signals. The lower arm operates in two positions only—"stop" and "caution." When the upper arm is in the "stop" position on account of a preceding train, the lower arm operates to the "caution" position, indicating that the "block is not clear—proceed prepared to stop within vision." If both the upper arm and the lower arm are in the "stop" position, the train must of course come to a stop, for the indication is that an opposing train is approaching. This could happen only if the opposing train "ran" the absolute signal.

CHAPTER VI

MAGNETISM AND ELECTRICITY

IN THE STUDY of magnetism and electricity, it is well to consider in advance just what electricity is and what its properties are. We find that no one knows the exact nature of electricity. We know that it is a method of transferring energy, but we know very little of the way in which this energy is transferred.

While we speak of electric current and the flow of electricity, we do not actually know that there is anything which would correspond to the flowing of a current such as we have in a river or in the water circulating in pipes.

We have found out, however, that by assuming that there is a flow of current we can explain all the actions that take place and can formulate certain basic laws, the results always corresponding to these laws. Therefore, from a practical viewpoint, since the results are the same as if there was an actual flow of current, we are justified in assuming that there is a flow of current.

Sources of Electric Energy—There are three sources of electric current commonly used in signaling:

1. Primary battery.
2. Generator.
3. Storage battery.

For all signaling purposes the storage battery is a source of electric energy and should be so considered.

Electric energy for signaling systems is derived as follows:

1. D. C. block from potash or storage battery.

2. A. C. block from some commercial current, and, for reserve, from a gas, oil or steam-driven generator.

3. D. C. interlocking from 110 volt storage battery charged by (1) A. C.-D. C. or (2) D. C.-D. C. motor generator set; (3) float charge direct from 110 volt commercial line or (4) float charge through resistance if 220 D. C., or (5) from rectifier if commercial current is A. C. If no commercial current is available (which is the exception these days) storage battery is charged by a gasoline, oil or steam-driven generator set.

4. A. C. interlocking from some commercial current through transformers, and, for reserve, from a gasoline or oil-driven generator which operates only when the main source is out of service. This is the only case where current from local generators is ever fed directly to a signal system—that is, to switch and signal mechanisms, track circuits, etc.

Fundamental Comparisons—The effects which come from an electric battery or generator can be compared to the effects set up in a water pipe whose ends meet, forming a complete circuit. If we have a pressure tank at one point and put the water under pressure of twenty pounds, we will, of course, force the water through the pipes and back again to the source, thus setting up a circulation of water. In this case the pressure would correspond to the electro-motive force of a current or a battery; the resistance of the sides of the pipe to the passage of the water would correspond to the resistance in the wire or rails of the circuit; and the volume of water which was circulated, depending not only upon the pressure but upon the size of the water pipe, would correspond to the quantity of electricity in a current.

That which corresponds to the resistance of the pipe walls to the passage of water is the resistance of the wire; and that which corresponds to the quantity of water which is pumped through the circulating pipe is the number of amperes discharged by the battery or generator in a given time. The number of amperes discharged per hour (ampere hours) corresponds to the number of gallons of water pumped through the pipe in an hour. The electro-motive force (E. M. F.) is the electrical power or force and corresponds, roughly, to the power or force the circulating water is capable of exerting.

With these simple fundamental comparisons it is easy to see that the higher the electro-motive force of a cell, the greater the amount of current that can be forced through a given wire or other conductor; and the greater the resistance of the wire (corresponding to the smallness of the pipe in water circulation), the less the amount of current that can be forced through it by a given voltage.

Effects of Electric Currents—As indicated above, we measure electric currents entirely by their effects, because there is nothing visible to show what is happening in the circuit when we close it. The three most important effects produced by an electric current when it is closed are (1) chemical effects, (2) heating effects, and (3) magnetic effects.

When a battery sets up a current, there is a chemical change which, as all signalmen know, gradually discharges the battery to a point where it must be replenished, or, in the case of a storage battery, where a new charge must be applied in the reverse direction from which the charge has been discharged.

Heat is always generated by an electric current, and the amount of heat depends upon the amount of resistance to flow. Ordinarily the heat in a circuit will be so small as to be unnoticeable, except in resistance coils, etc. When an ordinary conductor becomes hot, it is an indication that there is something wrong somewhere.

The magnetic effects of an electric current are the main thing in which the signalman is interested. When an electric current flows through a coil of wire wound upon a soft iron core, there is generated a magnetic power which attracts to the iron core magnetic substances such as iron, steel, etc.

The Ampere—The ampere is the practical unit for measuring the rate of flow of the current. This is the quantity of electricity which will flow through a wire having a resistance of one ohm, when the electro-motive force is one volt. It is not necessary for us to remember how the value of an ampere is determined, but merely to remember that it measures the quantity of current flowing, or the rate of flow.

An ampere-hour is the quantity of current which will be generated by a current of one ampere flowing for one hour.

The Volt—The volt is the unit measure of electromotive force or pressure. It is the electric pressure that will force a current of one ampere through a conductor whose resistance is one ohm. That is, if we have a conductor with a resistance of one ohm and electric pressure of one volt, a current of one ampere will flow through the conductor.

The Ohm—The ohm is the unit for measuring resistance. It is equal to the resistance offered to a

constant electric current by a column of 14.4521 grams of pure mercury at zero degrees centigrade. It is not necessary to remember these figures, but it is necessary to remember that the ohm is the measure of the resistance of a conductor to the passage of current.

The ohm is named after the man who first discovered the relation between electro-motive force, resistance (Ohms) and current quantity. This law is: "In any circuit, the current quantity in amperes which will flow is equal to the electric pressure in volts divided by the resistance in ohms." Written as a formula this is as follows:

$$\text{Current flowing (in amp.)} = \frac{\text{The electric pressure in volts}}{\text{The resistance in ohms}}$$

Ordinarily in electricity we use the following letters in writing this formula:

I = the current in amperes.
E = the electric pressure in volts.
R = the resistance in ohms.

Written with these letters the formula is $I = \frac{E}{R}$; also $E = I \times R$ and $R = \frac{E}{I}$. It is easier to use when written $E = I \times R$.

For instance, if we have a current (I) equal to ten amperes, and a resistance (R) of twenty ohms, the electro-motive force (E) will be found as follows by substituting in the formula $E = I \times R$:

$E = 10\ (I) \times 20\ (R)$ or

$E = 200$ volts.

If the current (I) is ten and the electro-motive force (E) is 100, we can find the resistance (R) by substituting as follows:

$100\ (E) = 10\ (I) \times R$ or

$100 = 10 \times R.$

$10\ R = 100.$

$$1\ R = \frac{100}{10} = 10.$$

$R = 10.$

If you have any *two* of the values, I, E and R, by substituting in this formula it is possible to find the third value.

These formulae are the basis of all electrical computations, and every signalman should become thoroughly familiar with them. When we want to test the strength of a current we use various testing instruments to find the voltage and the amperage. But in case we do not have these instruments, we must be able to use the above formulae.

Electro-Motive Force—The technical definition of E. M. F. is as follows: "The total electro-motive force is the total electric pressure generated in any circuit which tends to cause the current to flow." This means the pressure necessary to overcome the resistance of the battery plus the resistance of the external circuits.

Magnetism—There are two kinds of magnetism: (1) permanent and (2) temporary. Permanent magnets may be subdivided into (a) natural magnets and (b) artificial magnets. Natural magnets are sub-

stances found in the earth which will attract iron. An artificial magnet is the horseshoe magnet, with which everyone is familiar, to which magnetism may be given by an electrical current. There are other kinds of artificial magnets, and other forms, among which is the bar magnet, which is similar to the horseshoe magnet except that it is made in a straight bar and has magnetized poles at each end.

Temporary magnets only retain their magnetism as long as they are influenced by an outside magnetizing force. The electro-magnet in a relay is a temporary magnet. The armature will be attracted to the pole pieces only as long as a current is flowing through the coil. When the current is discontinued, the armature drops away.

The electro-magnet is of most interest to the signalman. It is upon the principle of electro-magnetism that the relay and many other signal instruments are based. The electro-magnet consists of a soft iron core surrounded by a coil of wire. When current flows through the coil, the electro-magnet attracts magnetic substances; and when the current is cut off, the coil and core exert no magnetic effect.

Magnetic Field—The magnetic field of a magnet is the region which is affected by the influence of its magnetic poles. The magnetic flux means the magnetic *lines of force* around the magnet. Any magnetic substance which comes within the range of a magnetic field tends to be influenced by it and to place itself in the direction of the lines of force around the magnet.

The electro-magnet obtains its magnetism through what is called induction. By induction we mean that it does not receive its magnetism by direct contact

with the electric circuit, but by being within the field of lines of force of the current.

We do not know what change takes place in a substance when it is magnetized; but from the actions which have been observed, it would appear that there is a change throughout the entire structure. For instance, if we have a long bar magnet, we will find that it attracts substances through either end, but not in the middle. But if we cut the same bar magnet in two in the middle, we will find that we have two magnets, each of which attracts at its ends, but not in the middle.

One of the laws of magnetism is that "unlike poles attract and like poles repel." In other words, if you have two magnets and place the poles together, there will be attraction between the magnets when placed in one position; but when they are reversed, the magnets will repel each other. This principle is used in the polarized relay.

Many signal instruments are based upon the principle that a magnetic substance, when placed in a magnetic field, will arrange itself in the direction of the field, if possible—that is, parallel to the lines of force of the field.

CHAPTER VII

MECHANICAL INTERLOCKING

AS before stated, interlocking is defined as follows: "Interlocking is an arrangement of switch and signal appliances so interconnected that their movements must succeed each other in a predetermined order." Thus interlocking differs from block signaling in that it pertains to movements over conflicting routes, whereas block signaling pertains to the spacing of trains on the same route.

About as simple an interlocking layout as we can imagine is that of a single track crossing at right angles, similar to Figure 42. All that is necessary in protecting this crossing in the way of signals is a home and distant signal on each route. Derails are placed near the home signals.

Purposes of Interlocking—The first purpose of interlocking is to eliminate as many stops as possible, and its second purpose is to safeguard train movements. Interlocking plants are only installed where they would effect more economical operation: For example, take the crossing of a heavy traffic line and a light traffic line. It is easy to determine how many tonnage-train stops could be eliminated by interlocking per day, month or year. The number of stops multiplied by the cost of each stop (about $3 on the average) represents the gross savings effected. Passenger-train stops eliminated are figured in like manner. If the total savings effected are in excess of the fixed charges—interest on investment, depreciation,

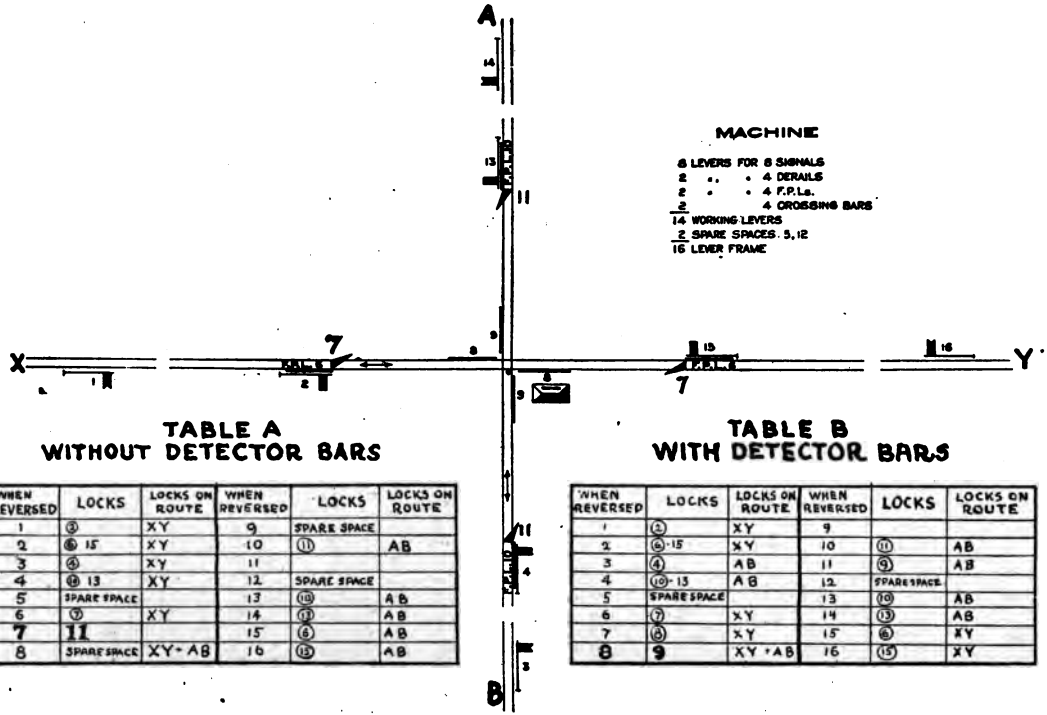


TABLE A
WITHOUT DETECTOR BARS

WHEN REVERSED	LOCKS	LOCKS ON ROUTE	WHEN REVERSED	LOCKS	LOCKS ON ROUTE
1	③	XY	9	SPARE SPACE	
2	⑥ 15	XY	10	⑪	AB
3	④	XY	11		
4	⑩ 13	XY	12	SPARE SPACE	
5	SPARE SPACE		13	⑩	AB
6	⑦	XY	14	⑬	AB
7	11		15	⑥	AB
8	SPARE SPACE	XY+AB	16	⑫	AB

TABLE B
WITH DETECTOR BARS

WHEN REVERSED	LOCKS	LOCKS ON ROUTE	WHEN REVERSED	LOCKS	LOCKS ON ROUTE
1	①	XY	9		
2	⑥·15	XY	10	⑪	AB
3	④	AB	11	⑨	AB
4	⑩·13	AB	12	SPARE SPACE	
5	SPARE SPACE		13	⑩	AB
6	⑦	XY	14	⑬	AB
7	⑤	XY	15	⑧	XY
8	9	XY+AB	16	⑮	XY

Figure 42.

operation and maintenance—a plant would be economical.

The foregoing are the main points, but other features, such as savings in time on acount of the elimination of stops, and increased facility for various shunting movements, should of course be considered.

Mechanical Locking—The mechanical locking in the interlocking machine is so arranged as to prevent the leverman from manipulating the levers improperly—or, in other words, signals cannot display "proceed" indications for conflicting routes. The standard code rules require that all levers remain in the normal position (signals at "stop" and derails open), and be reversed only for a train movement, after which they are supposed to be returned to normal. (This rule cannot be enforced in large busy plants.) In the case of a crossing, a route would be cleared or "set up" in the following sequence: (1) Reverse derails in route (which locks conflicting derails and signals normal), (2) reverse home signal, and finally (3) reverse distant signal. After a train has passed, the levers are put normal in reverse order—distant signal, then home signal and finally derails—the reasons for which are obvious. From the foregoing it is apparent that levers can be manipulated only in a predetermined order or sequence.

Numbering of Interlocking Units—The proper method of numbering the units of a plant depends upon whether the plant is power or mechanical. If power, signal levers are ordinarily located at the ends of the machines, with switch and derail levers between, sufficient spare levers or spaces being provided

in each group. In a mechanical machine with rocker shaft leadout, the same method can be employed as in power machines; but with crank or deflecting bar leadouts, the switch, lock and signal levers are ordinarily grouped together, the arrangement being such that the nearest unit on each side of the tower takes the pipe line nearest the rail, as it is the first to terminate, and so on. The proper numbering of a large complex layout requires considerable experience in order to accomplish the necessary locking with a minimum amount of locking parts.

Locking Charts—The proper locking for a layout like Figure 42 is shown in the tables. A circle around a number indicates "reversed." For instance, at the top of the locking sheet in Table "A," lever No. 1, when reversed, locks No. 2 in its reversed position; lever No. 2, when reversed, locks No. 6 in its reversed position and No. 15 in its normal position; lever No. 3, when reversed, locks No. 4 in its reversed position; lever No. 4, when reversed, locks No. 10 in its reversed position and No. 13 in its normal position; lever No. 6, when reversed, locks No. 7 in its reversed position; and lever No. 7, when reversed, locks No. 11 in its normal position. Table "A" is for an interlocking where detector bars are not used.

Detector Bars as a Basis of Interlocking—Where detector bars are used, the locking chart will be as shown in "B," in which case lever No. 1, when reversed, will lock lever No. 2 in its reversed position; lever No. 2, when reversed, will lock No. 6 in its reversed position and No. 15 in its normal position; lever No. 3, when reversed, will lock No. 4 in its re-

versed position; lever No. 4, when reversed, will lock No. 10 in its reversed position and No. 13 in its normal position; lever No. 6, when reversed, will lock No. 7 in its reversed position; lever No. 7, when reversed, will lock No. 8 in its reversed position; lever No. 8, when reversed, will lock No. 9 in its normal position, etc.

The above locking sheet has been explained in some detail in order that the reader may become perfectly familiar with the way in which the locking sheets are made up, if he is not already familiar with it from his past experience.

The key to the locking in Figure 42 is indicated by the route on which the different units lock. For instance, in the table showing the locking without detector bars, it will be noted that all the units, with the exception of units No. 7 and No. 11, lock only other units on their own route. Unit No. 7, however, is located on Route "XY," and unit No. 11 on Route "AB"; and it is on these units that the interlocking of all the other units is based. Table "A" shows that levers No. 7 and No. 11 are so interlocked that when either is in the reversed position, the other must be in the normal position. Running back up the column, we see that No. 7 is interlocked with No. 6; No. 6 with No. 2 and No. 15; No. 2 with No. 1; No. 7 with No. 11; No. 11 with No. 10; No. 10 with No. 13 and No. 4, etc.

Derails as a Basis of Interlocking—In the locking without detector bars, the key to the interlocking is in derails No. 7 and No. 11. When detector bars are used at the crossing, they are used as the basis of the

interlocking, in this case the units being No. 8 and No. 9. This fact is indicated in Table "B," with detector bars, which shows that No. 8 and No. 9 are the only two units on different routes which interlock with each other, No. 8 being on Route "XY," and No. 9 being on Route "AB."

This will explain the principle of locking at an interlocking plant: that first one unit of each conflicting route is interlocked so that, when in reversed position, it locks other conflicting units in normal position, the rest of the interlocking done on each route being built upon that particular unit.

By following the method indicated, it is easy to take any signal chart and discover what the key units are, and thus trace the plan which was pursued in laying out the locking.

In Figure 43, it will be noted that the derails are used as a basis for the interlocking, for by tracing down in column No. 1 we find that derail No. 11, when reversed, locks derail No. 15 on Route "MN" normal, and also locks derail No. 17 on Route "XY" normal. The rest of the locking for Route "AB" is then built upon unit No. 11; the rest of the locking for Route "MN" is built upon unit No. 15; and the rest of the locking on Route "XY" is built upon derail No. 17.

The key to the locking in Figure 44 is in derail No. 11 on Route "MN," derail No. 14 on Route "XY," and derail No. 17 on Route "XY." We have to go further than this, however, to find the basis of the locking between "AB" and the other routes, and the key is given by derail No. 22 on Route "AB," which locks with derail No. 17 on Route "XY."

This table is made and reads the same as the others

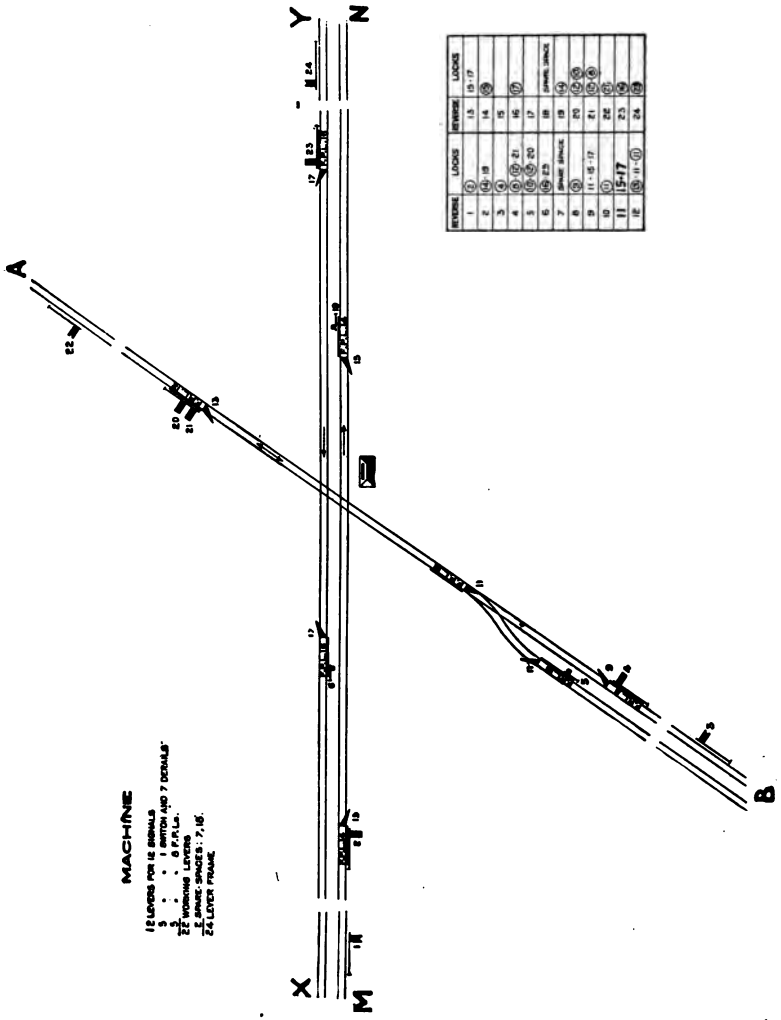

A
B
X
Y
M
N
MACHINE
12 LEVERS FOR 12 SIGNALS
5 " " 1 SWITCH AND 7 DOUBLE
5 " " 6 P.R.'s.
22 WORKING LEVERS.
2 SPARE SPACES : 7, 16.
24 LEVER FRAME.

Figure 43.

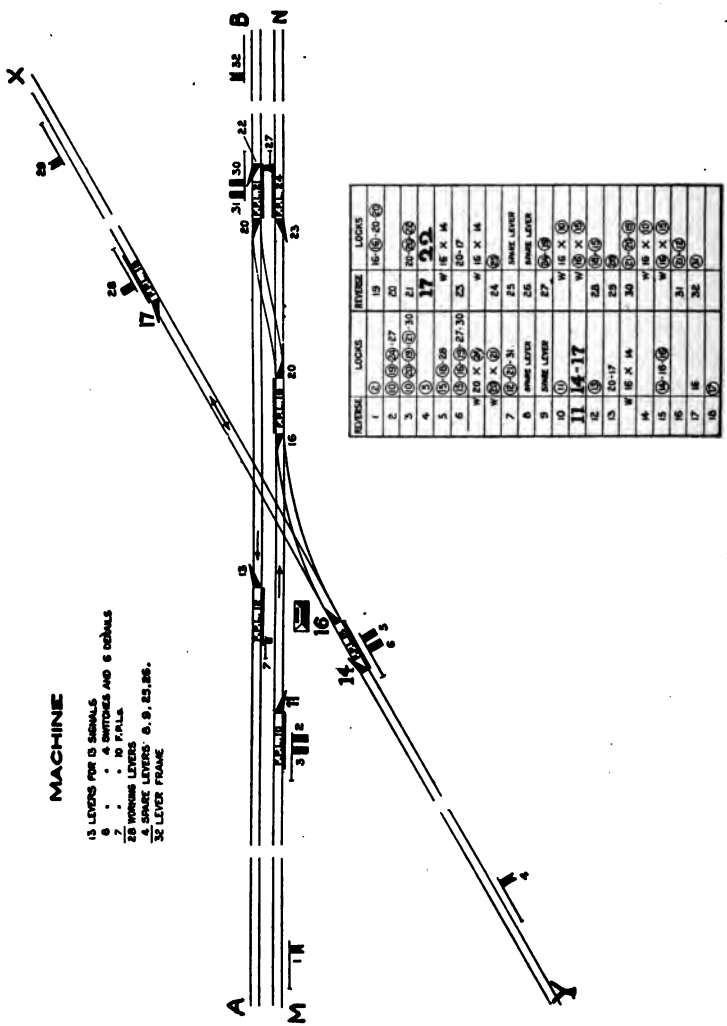

MACHINE
13 LEVERS FOR 13 SIGNALS
6 " " 4 SWITCHES AND 6 CROSSINGS
7 " " 10 FOULS
28 WORKING LEVERS
4 SPARE LEVERS 6, 9, 25, 26.
32 LEVER FRAME
A
B
M
N
X
Y
REVERSE
LOCKS
SPARE LEVER
W 16 × 14
W 20 × 14
W 16 × 16

Figure 44.

which were given previously, but for greater clearness the way to read a table is indicated again. Starting at the top of the table at the left-hand side: When lever No. 1 is reversed, it locks lever No. 2 in the reversed position; when lever No. 2 is reversed, it locks No. 10 reversed, No. 9 reversed, No. 24 reversed, and No. 27 normal; when lever No. 3 is reversed, it locks No. 10 reversed, No. 20 reversed, No. 19 reversed, No. 21 reversed, and No. 30 normal; and so on throughout the table.

There is a feature in this table which is not shown in the previous ones, and that is the letter "W" under lever No. 6. This "W" indicates what is called a "when dog" in the locking, which means that lever No. 6, when reversed, locks No. 15 reversed, No. 16 reversed, No. 19 reversed, No. 27 normal, and No. 30 normal, when—and only when—lever No. 20 is normal and lever No. 24 is reversed, or when levers No. 20 and No. 21 are reversed. At other times lever No. 6 does not lock Nos. 15, 16 and 19 reversed and Nos. 27 and 30 normal.

Thirty-two Lever Machine—Figure 45 shows a layout for a thirty-two lever machine. In this layout the interlocking of switches Nos. 14, 17 and 19 forms the key of the locking table. With these three levers properly interlocked, and each unit on each route locked with its key switch, it is apparent that it would be impossible to line up conflicting routes at the same time.

These few typical layouts make it possible for a signalman to grasp the underlying principles of interlocking and the basis from which locking charts

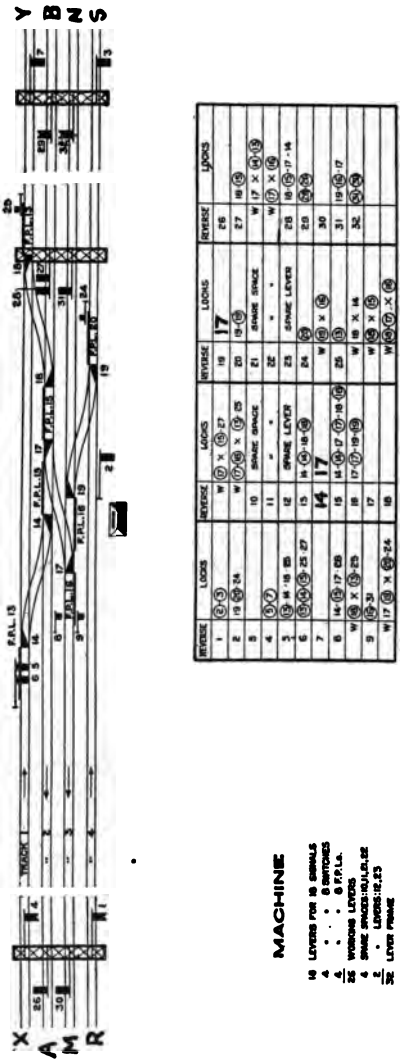

MACHINE
16 LEVERS FOR 16 SIGNALS
4 . . . 8 SWITCHES
4/24 . . . 8 F.P.L.'s.
24 WORKING LEVERS
4 SPARE SPACES:10,21,22,23
2/24 . LEVERS:12,23
LEVER FRAME
REVERSE
LOCKS
SPARE SPACE
SPARE LEVER

Figure 45.

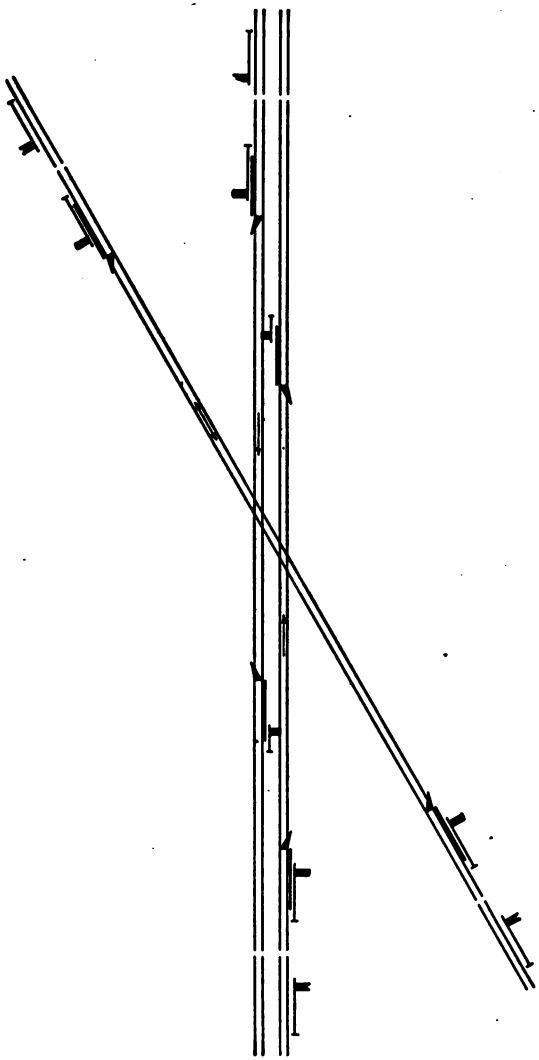


Figure 46.

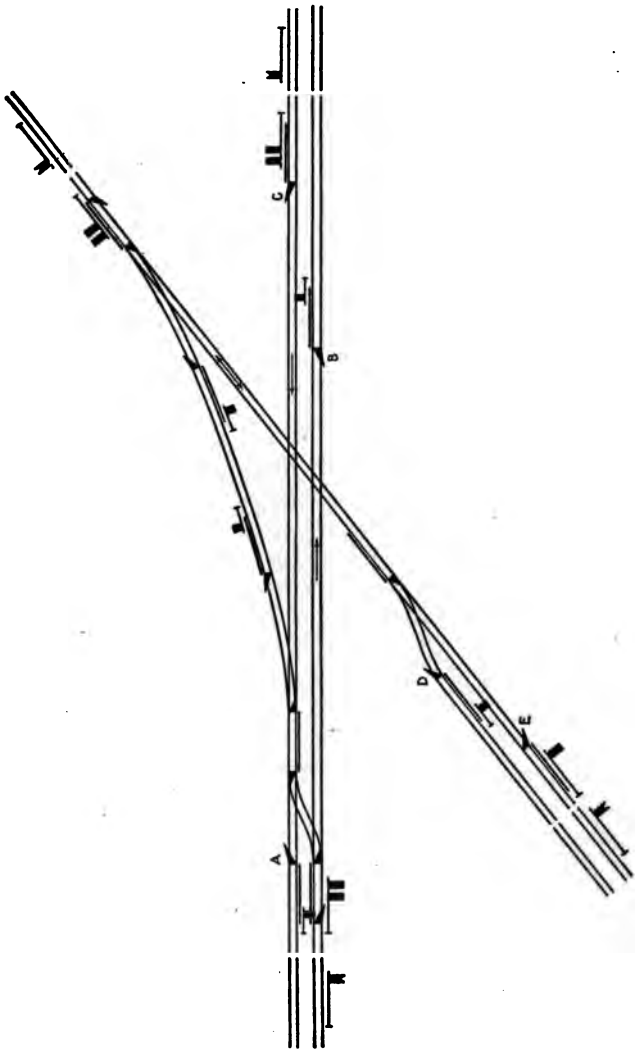


Figure 47.

are worked up. This knowledge is necessary in preparing locking sheets and dog charts.

Addition of a Wye-Track—Figure 47 shows a layout similar to Figure 46, in which a wye-track has been added without changing the number of units which must be operated by the signal machine (interlocker).

In Figure 47 two derails are dispensed with, and the switches are so interlocked that if the signal is at "stop," the train will have to take the curved wye-track and will thus be deflected from the main line, when the engineman can bring his train to a stop. This is a simple addition to the plan shown in Figure 46. It is easy to imagine another wye-track, such as the one illustrated, connecting the same two tracks in like manner on the opposite side of the crossing. The addition of switches for sidings is another step which might be illustrated, but one which it is hardly necessary to illustrate, as the protection would be similar to that shown.

The double-track crossing, combinations of a double track with a single track, three tracks or more, cross-overs, switches for branch lines, etc.—these units are added in many plants; and although they result in very complicated interlocking layouts, they are all based upon the simple principles explained.

Figure 47 illustrates a double-track crossing with a single track, without any complications, showing, however, the use of low speed or back-up derails on double track.

Interlocking Leadouts—In a modern mechanical interlocking plant, switches, derails, facing point locks and bars, home signals and dwarf signals are ordi-

narily operated by pipe lines. Most distant signals and often some home signals are power operated, being controlled by a circuit controller mounted on the machine and actuated by a latch on the lever. The A. R. A. does not sanction the use of wire operated signals.

Mechanical interlocking machines have either horizontal or vertical leadouts. The leadout is the connection from the lever of the interlocking machine to the pipe or wire lines which operate the units out on the track.

The machines commonly used at present are the S. & F. and the Style "A," both of which have latch locking.

There are also machines called "dwarf interlocking machines," which are used where a number of yard switches can be controlled advantageously from a central point, or where it is necessary to have temporary interlocking, or at points where the installation of a heavy and expensive interlocking machine would not be justified.

A leadout in a mechanical plant includes all the various parts which connect with the "up-and-down" rods attached to the interlocking machine and which transmit the movement of the levers to the pipe line.

The leadout comprises two parts: First, that part attached to the lower ends of the up-and-down rods, which changes the direction of movement from vertical to horizontal; and, second, that part which connects to the pipe lines. The former may be (1) vertical cranks, (2) vertical deflecting bars, or (3) rocker shaft; and the latter may be (1) horizontal cranks of various types, (2) horizontal deflecting bars, or (3) rocker shaft. The rocker shaft arrangement is quite

generally favored, as it is best adapted to changes and alterations, which frequently occur. The A. R. A. has standard plans covering the several types of leadouts, including the foundations.

A horizontal leadout is used on a machine which is to be placed at or near the ground—practically on a level with the pipe line. A vertical machine is used in towers where the bottom of the levers may be several feet or more above the level of the pipe line.

The type of leadout shown in Figure 48 is the box crank type; and Figure 49 shows what is called a deflecting bar leadout. The operation of the crank leadout is probably familiar to every signalman. The deflecting bar leadout is also simple in operation. The deflecting bar is circular in form and is contained within a box which acts as a bearing. When the lever is pulled, this circular bar moves in its circular bearing and thus changes the direction of motion.

The deflecting bar leadout is not as satisfactory for sharp angles as is the crank arm; but where the angle is 90 degrees or more, the deflecting bar is found to give satisfaction.

The rocker shaft leadout is a modification of the crank arm. Arms corresponding to the crank arms are fastened to a rocker shaft, but in the vertical position. The advantage is that a rocker-shaft crank can be connected to any one of the pipe lines by being shifted along the rocker shaft.

Where a number of crank arms are located at the same point, as shown in front of the tower, it is found advantageous to place the cranks in what is called a crank box. Figure 50 illustrates a four-way box

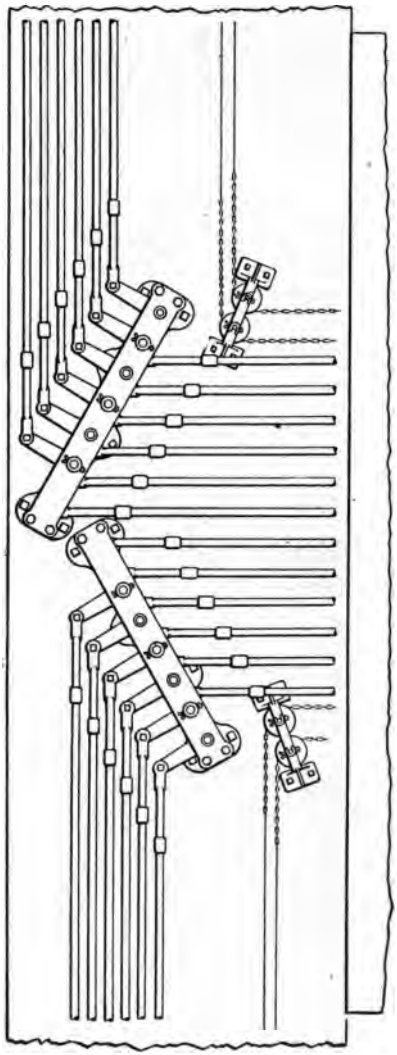


Figure 48—Box Crank Leadout.

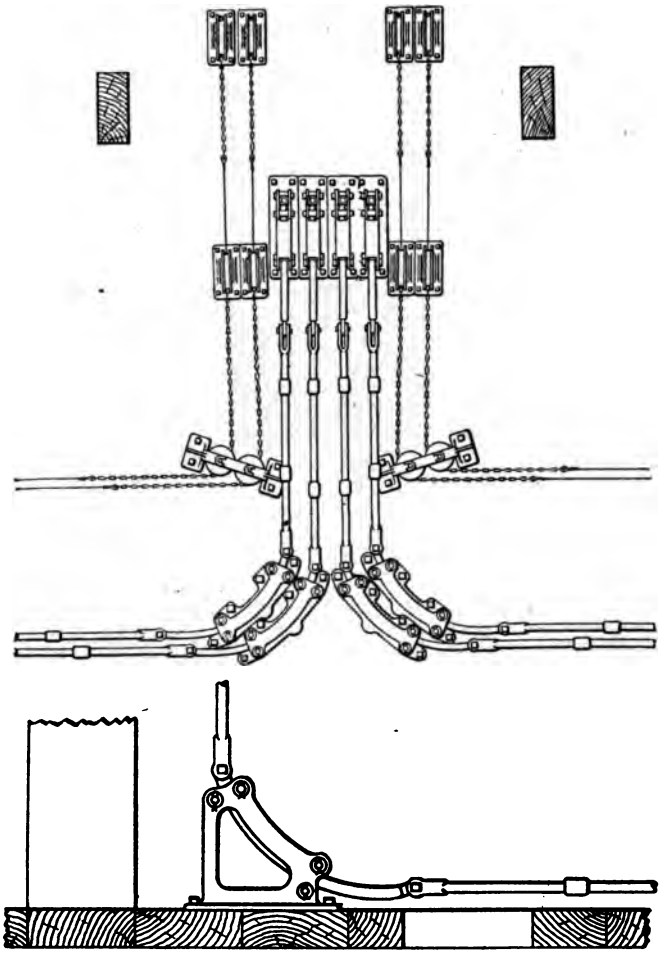


Figure 49—Deflecting Bar Leadout.

crank. Various other arrangements are possible with boxes comprising more or less cranks.

The construction of the deflecting bar, with its connection in the pipe line, is shown in Figure 51.

Where pipe lines have to be carried through crossings, it is best practice to install oil pipes and stuffing boxes, which are made with packing at either end to exclude dirt or water. The stuffing box acts as a bearing for the pipe line and must be kept free from

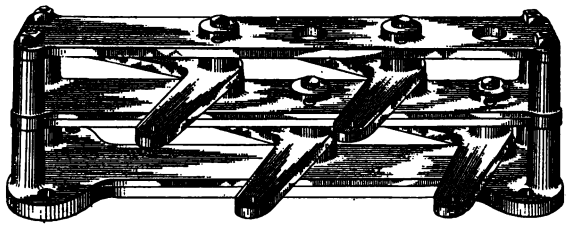


Figure 50.

dirt or grit, in order that the pipe line may operate correctly.

Pipe Line Foundations and Carriers—Pipe lines must have firm foundations and suitable carriers or bearings at each point of support. If one foundation

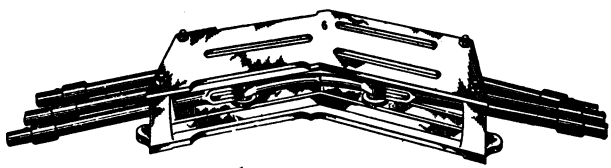


Figure 51.

sinks out of level or line with the others, or if it shifts, it will create a kink in the pipe line, which will cause the pipe line to bind and thus make its operation diffi-

cult. Furthermore, the shifting of a foundation which allows a pipe run to get out of line tends to shorten the pipe line and makes necessary an adjustment for the operation of some of the units.

Pipe-carrier foundations are concrete blocks 8x12x24 inches, which support wood (oak) or iron strips, to which the pipe carriers are attached. Hook bolts secure the supports to the concrete blocks. The crank or compensator foundations comprise mass concrete, finished on top, embedded in which are cast-iron piers, to which the cranks or compensators are attached.

Where a number of pipe line carriers are to be placed upon a single foundation, a pipe line carrier base is ordinarily installed. This base may be fastened

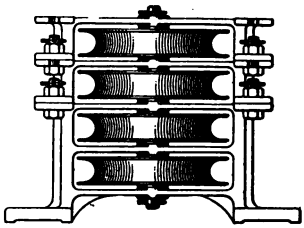


Figure 52.

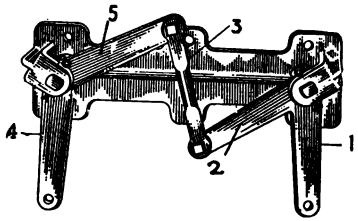


Figure 53.

to the concrete foundation with two or more bolts, and the pipe line carriers then attached to the base by means of carriage bolts, which fit in the slots of the base. This installation makes necessary only two anchor bolts in a concrete foundation, and it is much easier and more satisfactory.

Pipe Line Compensator—An important part of the pipe line is the compensator, which is so constructed that it compensates for changes in lengths of the pipe line produced by variations in temperature.

The compensator used most is illustrated in Figure 53. It consists of two crank arms, No. 1 having an acute angle and No. 4 an obtuse angle, which are joined by connecting link No. 3. One end of the pipe line is fastened to the hole in the lower end of crank No. 1, and the other end is connected to the hole in the lower end of crank No. 4.

When the pipe lines at the right and left of the compensator contract or expand, they move arms No. 1 and No. 4 toward each other, these in turn moving their other arms; but the only effect is that the angle of link No. 3 is changed. In other words, if the pipe line is contracting, it pulls on arm No. 4, which moves to the left, arm No. 5 then moving toward arm No. 2. At the same time, however, the pipe line to the right is pulling arm No. 1 to the right, and this moves arm No. 2 down, or away from arm No. 5. The two crank arms are made with angles of 60 and 120 degrees, respectively, so that this movement of No. 2 and No. 5, which is in the same direction, will be equal. When it expands, the pipe line to the left moves arm No. 4 toward the right, which will tend to raise arm No. 5 upward; but at the same time the pipe line to the right of No. 1 will be pressing No. 1 toward the left and raising arm No. 2 upward in the same direction as arm No. 5 is being moved. Thus, no matter what happens, arms No. 2 and No. 5 move in the same direction and their movement is equal, temperature changes affecting the angle of link No. 3 only.

A compensator changes the direction of movement in a pipe line. That is, if there is a push movement on one side of the compensator, there will be a pull movement on the opposite side.

These movements are equal, however, only if the compensator is located at the center of the pipe run, and if there is no reverse crank in the pipe line. In finding the center, we measure from just outside the tower clear up to where the pipe line fastens to the switch rod, or signal rod, including the pipe line leading from the straight run to the unit operated.

Compensation for pipe lines is measured from the outside of the tower, as the temperature inside is assumed to be uniform.

A straight arm may be used as a compensator by cutting a pipe line in the middle and placing the arm at approximately right angles, one side of the pipe line being attached to one end and the opposite side to the other end of the arm. This method throws the whole pipe run out of alignment, however, and for this reason is seldom used unless there is only a single pipe line.

The Signal Division of the A. R. A. has adopted the following recommendations for compensators: "Compensation shall be provided for each pipe line more than fifty feet in length and less than 800 feet, with crank arms 10x13 inch centers. From 800 to 1200 feet in length, crank arms shall be 10x16 inch centers. Pipe lines over 1200 feet in length shall be provided with additional compensators. Not more than 725 feet of pipe shall be compensated by a 11¾x11¾ inch crank."

Wire Compensator—The use of wire lines is not considered to be good practice in modern interlocking, but a good many old interlocking plants have them.

The expansion or contraction of a wire run is taken

care of much more easily than the expansion or contraction in pipe lines.

A wire compensator may consist of a weight on an arm placed at a signal, as shown in Figure 54. This weight assures that the wire will be kept tight at all times. As the wire contracts, this weight will rise, and as it expands, the weight will lower.

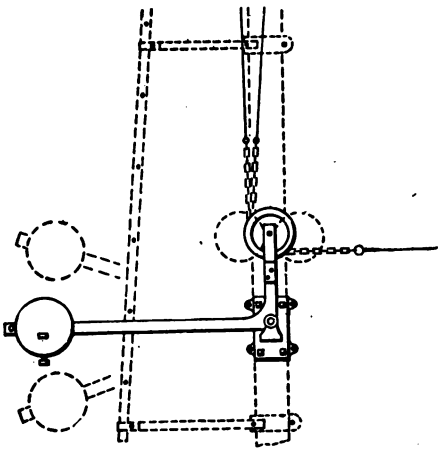


Figure 54.

Another form of compensator is based upon a weight hung on the wire line at some point, the weight being sufficiently heavy to keep the wire tight. When the temperature rises and the wire run expands, this weight will lower, and when the wire contracts, the weight will rise. This kind of compensator is often placed in the tower building. It is evident that the wire line compensator need not be put in the middle of the wire run, the reason for this being that the wire run is not a rigid connection, as is the pipe line. It does not make any difference if there is more wire on

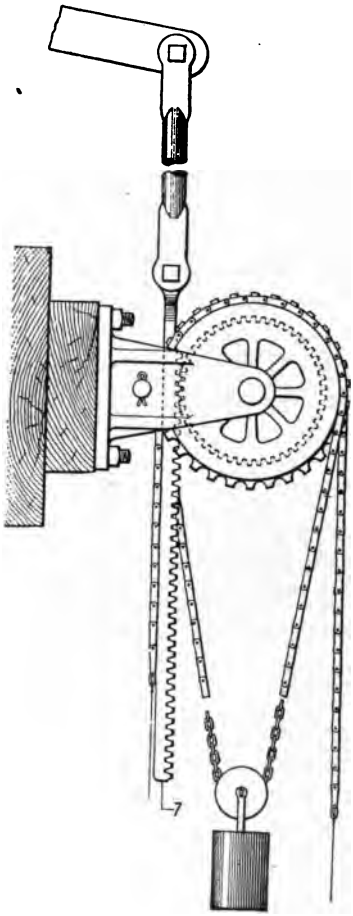


Figure 55.

one side of the weight than there is on the other, provided the weight is so hung that it can move freely on the wire and not have to apply its entire weight to one side or the other of the loop of wire on which it is attached. Figure 55 shows this kind of wire run compensator.

Bolt Lock—There are a number of locking devices based upon the principle of the bolt lock, which consists of a bar attached so rigidly to the switch, or other moving units, that when the switch is moved, the bar moves with it. At a certain place in this bar, there is either a slot or a bolt hole, so located that it is just in line with the bar or bolt when the switch or derail is closed. After the switch is operated, the bolt is moved forward; and if the hole is in line with the bolt, the latter passes through the hole. When the hole does not register with the bolt, the bolt strikes the side of the locking bar and prevents the movement of the lever in the tower from being completed, this in turn hindering the locking in the interlocking machine from releasing other levers.

Modifications of the bolt lock are used for lift rails at bridges to indicate when they are in place, and also at movable point frogs, etc. While they may be called lift rail locks, movable frog point locks, etc., where they operate upon the principle of the bolt registering with a hole in the bar, they are simply the bolt lock adapted to special uses.

Mechanical Interlocking Plants—The principles underlying locking which were described previously apply alike to all kinds of interlocking, whether mechanical, electro-mechanical, electro-pneumatic, or

electric, but of course the means of operation are different.

In mechanical interlocking, both the control of the units and the power for moving them are furnished manually by the leverman. Under these circumstances, it is necessary that the actual power required to operate the levers be kept at minimum by proper installation and maintenance.

An electric motor or pneumatic machine may operate a switch or other unit when it works with considerably more than normal resistance; but the same amount of resistance at a mechanical plant would prevent a man from operating the unit.

Mechanical Interlocking Machines—Figure 56A shows plainly how the locking is accomplished in a Saxby and Farmer locking machine of the ordinary type. The bars marked No. 1 in this illustration are forced in the direction of the arrow by the leverman when he pulls or pushes on his levers. On this locking bar is located the locking dog marked No. 2, which under certain conditions of locking prevents the bars from moving.

It will be noted that dog No. 2 butts against cross locking No. 3, and that therefore it would be impossible to push bars No. 1 in the direction of the arrow. It will also be noted that bars No. 5 can be moved in the direction of the arrow because cross locking No. 3, being toward the left, allows locking dog No. 4 to slide by. The condition shown in Figure 56A indicates that bars No. 1 control a rod operating a unit which conflicts with the unit operated by bars No. 5.

In Figure 56B the opposite condition is shown. It is

possible to operate bars No. 1 because cross locking No. 3 has moved to the right and in so doing has locked bar No. 5, dog No. 4 being held by cross locking No. 3. This explains in a simple way the basis of the operation of the locking of a Saxby and Farmer machine.

Figure 57 shows the lever of a Saxby and Farmer machine through which the movement of locking bars

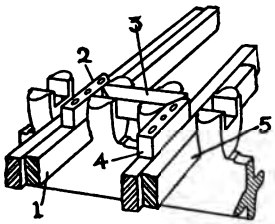


Figure 56A—Saxby and Farmer Locking.

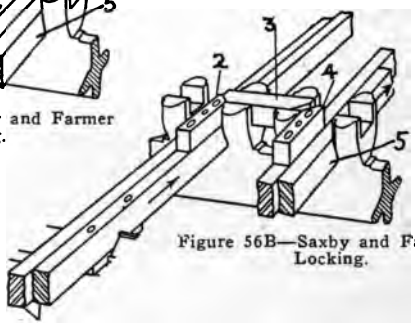


Figure 56B—Saxby and Farmer Locking.

No. 1 and No. 5 in Figures 56A and 56B is produced. It will be noted in Figure 57 that when the latch marked No. 2 is opened, the lever can be pulled backward (to the right), which will raise arm No. 13 at the left-hand side and lower arm No. 12 at the right-hand side. Part No. 13 is called the front tail and part No. 12 the back tail of the machine.

Locking bars No. 1 and No. 5 shown in Figures 56A and 56B are operated by the locking bar driver marked No. 20 in Figure 57. This movement is accomplished through crank arm No. 18 and rocker No. 8. As the

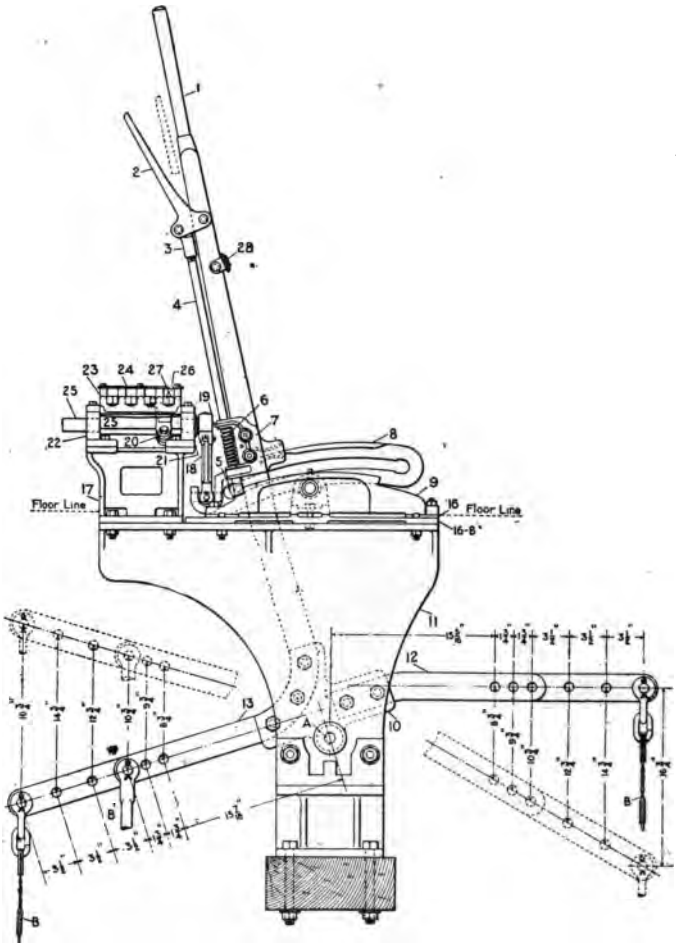


Figure 57.

lever is pulled back toward the right, it gradually depresses the right-hand end of rocker No. 8, and this raises the end of universal link No. 18, which in turn rotates crank No. 19 and locking bar driver No. 20. Locking bar driver No. 20 is an arm connected to the locking bar, and when the locking arm moves, the bar must move with it.

The front and back lever arms at the base of the lever are used for connections to the up-and-down rods.

Mechanical interlocking machines are usually made for vertical connections, but in cases where the tower is on or near the track level, the machine is arranged for horizontal connections.

Maintenance—It is evident that any looseness of the parts of a mechanical interlocking machine, or the dropping of bolts or nuts into the interlocking bed of the horizontal locking, will result in trouble—probably in breakages as well as obstructions to the operation of the plant. It is therefore necessary to inspect carefully mechanical interlocking machines to be sure that all parts are tight and correctly aligned. The lubrication of the machine should also be given special attention, for when the machine works hard the leverman is more likely to strain some of the parts when he is throwing his levers.

While it is necessary to oil the bearings of the interlocking machine, an excessive amount of oil should not be used, because it gathers dirt and also is likely to harden. Graphite is a good lubricant for the locking, but other lubricants may be used if graphite is not obtainable.

CHAPTER VIII

POWER INTERLOCKING PLANTS

POWER Interlocking—Power interlocking has been used to a considerable extent in the United States for plants of greater magnitude since 1890. The early hydraulic and hydro-pneumatic plants were followed by electro-pneumatic and electric ones. Modern power interlocking is either electro-pneumatic or electric, the type used being generally that which is best adapted to the individual location, or that which may be preferred by the signal engineer of the railroad concerned.

The question of the means to be used for storing and transmitting power at an interlocking plant should be considered in the light of the work to be performed. The functioning of a power interlocking switch or signal comprises control, operation and indication. The control and indication functions do not require much energy, although this may be made to exert itself continuously in order to provide the greatest protection. The operation of an interlocking unit, however, requires comparatively heavy expenditure of energy for a very brief space of time. For example, a switch movement requires approximately 3.0 amperes at 110 volts for two seconds in unlocking the switch points, throwing them, and locking them in the alternate position. A signal requires approximately 1.0 ampere at 110 volts for possibly seven seconds in clearing from zero to 90 degrees.

With the single exception of the interlocking machine, no part of a power interlocking is more important than the power plant, comprising the means for developing and storing the energy used for operating the switches and signals. The supply of energy may be obtained commercially, in which case it is usually in the form of alternating current at 110 volts; or it may be obtained by the use of a gasoline engine. A switchboard is required, and storage battery for storing the electrical energy, and, in electro-pneumatic plants, a reasonable capacity in condensation tanks and air lines for storing compressed air. It is generally considered best to have two sources of power supply available, or at least to have duplicate sets of apparatus, to protect against a breakdown.

Electro-Mechanical Interlocking—Electro-mechanical interlocking is a comparatively recent development in signaling, and it was devised to fill a very definite need. The difficulty of operating distant signals by long wire runs, and the ease with which distant signals can be operated by electricity, were two reasons for its development.

Again, many old mechanical interlocking plants had to be enlarged to take care of additional units in the track and signal layouts. This meant practically the rebuilding of the entire plant and the installation of larger mechanical interlocking machines in the tower. However, by adding a number of electric levers and rebuilding the locking of the mechanical levers, the plant could be enlarged without greatly disturbing the existing layout.

There was still another feature which favored the adoption of electro-mechanical interlocking, and that

was the gradual increase in the use of electric automatic block signals, which, when installed, had to be carried through mechanical interlocking plants. This made advisable the addition of automatic features to the interlocking signals, in order that they would work in harmony with the automatic block signals.

The electro-mechanical interlocker consists of a mechanical interlocking machine, above the levers of which is located a row of small levers which control the operation of the power-operated units. It is evident that the locking in the machine must be so arranged that there is mechanical locking between the electric and mechanical levers.

A generator is not necessary unless storage battery is used, and even then, if the commercial current is A. C., a rectifier would be used. Potash cells are used as often or oftener then storage battery. Frequently at an electro-mechanical plant, signals and track circuits are A. C., in which case a transformer would be used.

Electric signals (home and distant), and also track circuits, various types of electric locking, etc.,—either D. C. or A. C.—are often installed in connection with mechanical plants.

The use of electric power in an electro-mechanical plant is not confined to the operation of distant signals. In fact, it is possible to use the electric power for any purpose desired; and it is often used for operating all the units which are added to the old plant, which would otherwise require additional mechanical levers. This makes it unnecessary to add any mechanical levers to the machine, or to add or change the pipe runs with their foundations.

Primary battery of the caustic soda type may be used to supply energy for the electric units of an electro-mechanical interlocking plant. Storage battery may also be used for this purpose. The development of rectifiers, of both the vacuum tube and mechanical type, has recently made the charging equipment for battery of this sort from an A. C. source economical as well as simple. The electrical energy available in an electro-mechanical plant can be used for relays controlling signals, for annunciators, indicators, electric locks, and, if desired, for the electric lighting of signals.

The use of electric power in an electro-mechanical plant is not confined to the control apparatus mentioned and distant signals, but may be used for the operation of outlying switch movements by having a separate battery located adjacent to these. Thus additions to an existing interlocking plant can be made with minimum changes in interlocking machine, pipe lines, etc. The wires which conduct the electricity used for controlling various units are carried upon pole lines or in trunking or conduit, as desired.

Electro-Pneumatic Interlocking—Electro-pneumatic interlocking utilizes electricity for control and indication, and compressed air for the operation or actual moving of the switches and signals. Thus the wires used for transmitting electricity can be made small without undue losses, and, at the same time, advantage can be taken of the negligible resistance offered to the passage of air through the pipe lines.

The modern electro-pneumatic interlocking plant may use air at either ninety pounds or sixty pounds

normal pressure, with a generous allowance even below this. Direct current electrical energy at ten volts or alternating current at 110 volts supplies the control and indicating magnets. The circuits are simple, because control and indication are separated absolutely. The "SS" system of signal control is used, this providing not only a continuous indication of the position of each and every switch, but also the *continuous* control of all signals governing train movement over switches, no matter whether these are facing or trailing point.

The most recent development of the electro-pneumatic system is the use of the cut-off valve, which allows air to be retained in the air line but not the switch cylinders normally, this resulting in considerable economy; also the use of compressed air at sixty pounds pressure instead of ninety, this also being an economical advance.

The Union Switch and Signal Company's Model 14 electro-pneumatic interlocking machine has levers which are arranged for operation from left to right. These levers are provided with latches, by means of which they are held in both the normal and reverse positions, thus preventing accidental manipulation. All of the operating parts of the interlocking machine, except the levers, are enclosed in a sheet steel case, which is provided with cabinet locks. The mechanical locking, which determines the sequence of operation of the levers, is the Saxby and Farmer type, but in miniature, thus taking advantage of the many years' experience with mechanical interlocking machines, and applying this to a power machine where the strains on the locking cannot be so great.

But one lever is used for the control of any number of signal blades, of which only one can be cleared at a time: for example, blades governing train movements over converging routes, or opposing train movements. Similarly, a single switch lever in the Model 14 machine can control both ends of a crossover, or any other arrangement of switches which can be moved simultaneously without restricting traffic.

Direct Current Electric Interlocking—In electric interlocking, there are no rigid mechanical connections, such as pipe runs or air pipe lines, between the tower and the signal and track units to be operated. Thus all wear on mechanical connections such as are found in pipe and wire lines, and all trouble resulting from expansion and contraction, are eliminated. There is no leadout in an electric plant, and there is also a great reduction in the number of moving parts to be maintained and kept in operation during snow storms, etc. Besides, signal towers may be made smaller, and one man may operate many more units because very little physical exertion is required.

The main functions of the G. R. S. electric interlocking system are as follows:

1. *Control.* The G. R. S. machine is of the unit-lever type, in which each lever, with its locking connector, circuit controller, indication magnet, etc., is a unit by itself and may be added to or removed from the machine without disturbing other levers.

2. *Operation.* The operation in itself is one of the simplest features, for about all that is required is a properly designed motor for the particular service.

3. *Dynamic Indication.* When an electric motor at a switch or signal location speeds up to operate the unit from one position to another, it gradually gains speed until it reaches the maximum; and when the movement of the unit is entirely completed, there is a tendency for the rotating member of the signal motor to keep on turning because of its own momentum, and to come to rest gradually through friction. This fact is utilized in the G. R. S. electric interlocking plant to send back to the tower the indication that the unit has moved properly.

Probably all the readers of this book know that an electric generator and an electric motor are built almost exactly alike, and that if you pass current through from some source of energy, this current will make the motor operate. On the other hand, if there is no source of electric current, and if we turn the rotating member of the motor by hand, it will act as a generator and will generate current. In the G. R. S. interlocking, current is first supplied the motor, and the motor operates the unit. When the movement of the unit is completed, the current is cut off, but the rotating member of the motor continues to turn for a short time and in so doing generates another current which is carried to the tower and operates the indication. It will readily be realized that this is a very dependable indication, for the motor cannot act as a generator as long as it is acting as a motor to move the unit.

This is what is called "dynamic indication," and it means an indication by an electric current generated by the same motor which operates the interlocking unit.

4. *Cross Protection,* or means of preventing improper or unauthorized movements of the switch and signal mechanisms. In the G. R. S. system, current always flows in the same direction, whether for operation or indication; and if a cross or short circuit should occur, the current would flow in the opposite direction and cause the opening of the polarized relays and the main circuit breaker, thus announcing to the leverman that something is wrong.

Formerly, G. R. S. electric interlocking was usually installed with a main common wire for signals and another for all other units—low-speed signals, switches and derails. Sometimes in large plants there were two or three main common wires for each of the above, comprising what is known as sectionalizing. The trend of present practice is to provide an individual return wire for every unit; and although about 20 per cent more wire is required, there is the big advantage that, in case of a short circuit or other trouble, the only unit affected is that on which the trouble occurs. Individual return wires have been standard on the New York Central R. R. for some years.

In the General Railway Signal Company's electric interlocking plant, switches and signals are operated by electric motors, the current being furnished by storage battery.

The interlocking machine levers are locked mechanically as well as electrically, the mechanical locking being similar to that provided on mechanical machines. To each of the levers in these machines there is attached a circuit controller, through which the respective switch or signal mechanism is controlled.

When it is desired to line up a route, the signalman

pulls the first lever; but he can only make a partial movement of this lever, the completion of the movement depending upon the "dynamic indication" which comes from the unit itself, but which only comes after the unit has operated to its proper position. This indication releases a lock upon the lever, which allows the leverman to complete the stroke of the lever.

In the G. R. S. type of interlocking machine, the levers are pulled out to reverse or pushed in to normal. The preliminary stroke is about three-fourths of the final stroke, and the locking is so arranged that no conflicting levers can be manipulated until the full stroke of the first lever has been completed.

The locking in the G. R. S. machine is vertical and is like that in the Standard mechanical interlocker, but smaller in size.

During the first part of the movement of the lever in this machine, the tappet bar is moved one-half its stroke, but no change is made in the electrical connection. This preliminary tappet movement, however, locks all other levers conflicting with the new position of the lever in question.

Not until the final part of the lever stroke has been completed will all levers not conflicting with the new position of this lever be released. The lever cannot be placed either full normal or full reverse unless the the proper indication is received from the unit being operated.

The power switch board for a G. R. S. machine has an ammeter and a voltmeter, controlled by switches, to record the battery charging or discharging current, and the battery or generator voltage, respectively. A rheostat is provided to open the circuit when

the generator voltage is less than battery voltage, or to prevent discharge of the battery.

A circuit breaker which operates on the closed circuit principle is located on the operating switch board. It is so controlled that it is opened by the improper application of current to any circuit or unit in the plant, and in this way cuts off all operating current and puts out of service the entire plant, or in some cases the sections of the plant affected.

If the circuit breaker is closed by the leverman before the trouble has been removed, it immediately opens again; and any attempts on the part of the operator to plug the circuit breaker or hold it might result in serious trouble.

These circuit breakers are polarized and are inserted in series in each indication circuit in the tower. The current which passes through one of these circuit breakers will always be in one direction if the unit is operating properly. Current from an unauthorized source would have two paths to follow; and the following of the path through the polarized circuit breaker would promptly open the circuit breaker and cut off current from the unit.

As both positive and negative connections are broken through this circuit breaker, it gives a full measure of protection for the proper operation of the interlocking plant.

This feature, together with others for preventing false operation of interlocking units, was developed to guarantee the proper protection against foreign currents and crossed wires. Because of the great number of circuits which must be used in a large interlocking plant, this protection is exceedingly important in safe-

guarding the movements and in insuring proper operation of the interlocking plant.

The type "F" system of electric interlocking, manufactured by the Union Switch and Signal Company, maintains the same basic principles as in their electro-pneumatic system. The Model 14 interlocking machine, used in the type "F" system, is practically identical with that for the electro-pneumatic. The only real difference between the two systems is that electricity instead of compressed air is used for the *operation* of the switches and signals in the type "F" system. The principal detail in which the Union type "F" system differs from other electric interlocking systems is in the use of busses, or main wires, for supplying energy throughout the plant. The control and indication of switches and signals in the type "F" system are similar to the electro-pneumatic. A single pair of wires is used to supply energy for operating switches and signals, and these are made large in order to keep the drop in voltage at a minimum between the interlocking tower and the movements. These mains can also be used in connection with any other power demands which may be made throughout the interlocking plant.

The control, indicating and operating circuits are separated to insure against effects of crosses, grounds, etc., and to allow the maintainer quickly to locate any case of trouble which might develop: for example, wires broken due to derailment, or corroded due to action of the elements.

The switchboard wiring for the type "F" electric system is remarkably simple, because no special cross

protective apparatus is required, the protection in this system being obtained in the absolute separation of control, operating and indicating circuits, and the consequent avoidance of dual functioning of any of these circuits.

The Federal Signal Company has recently developed a system of electric interlocking utilizing current of one charactertistic for the operation of switches and signals, and current of another characteristic for the indication of these devices. For example, the switches and signals may be made to operate on direct current and to indicate by means of alternating current, or these units may be made to operate on alternating current and to indicate by means of direct current.

The interlocking machine has built into it an arrangement of magnets which can be made to operate on current of one characteristic and not on current of the other, in this way preventing a switch or signal from indicating by means of a current similar to that on which it operates.

Alternating Current Electric Interlocking.—Alternating current may be applied to Union type "F" electric interlocking without any changes whatever in the basic principles involved or in the circuits, except that a transformer is substituted for the battery. By means of individual transformers at the various switches, absolute separation of each pair of switch indicating wires can be obtained if desired.

CHAPTER IX

PRIMARY BATTERIES

BATTERIES for Track Circuits—As the track circuit battery is discharging current practically all the time, the kind of battery to use is the one which will last the longest and give the best service.

The main requirement is high internal resistance, as, for example, in the gravity cell, which has an E. M. F. of one volt. Both the potash cell (E. M. F. about 0.6 volt) and the storage cell (E. M. F. two volt) have low internal resistance; but this is overcome by installing a fixed or variable resistance unit in series with one or both of the battery leads. Each D. C. track circuit is operated by two or three cells connected in multiple, the reason for which is that, if one cell should fail, the other one or two continues to function.

The arrangements of track battery cells are shown in Figures 59, 60, 61, 62 and 63. Opposite each of these layouts in standard R. S. A. symbols are also shown sketches of actual cells and the way they should be connected. All signalmen know how two cells are connected in series, so no illustration of this is shown. When connected in this way, the voltage or current pressure from one cell is added to that of the other cell.

Cells Connected in Series or in Parallel—Probably most signalmen realize the different results obtained when cells are connected in series or in parallel; but a simple illustration will serve to explain this quite clearly.

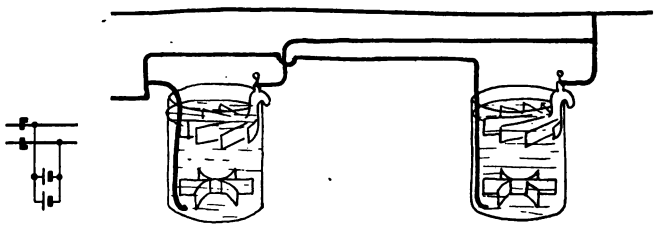


Figure 59—Two Cells in Parallel (or Multiple).

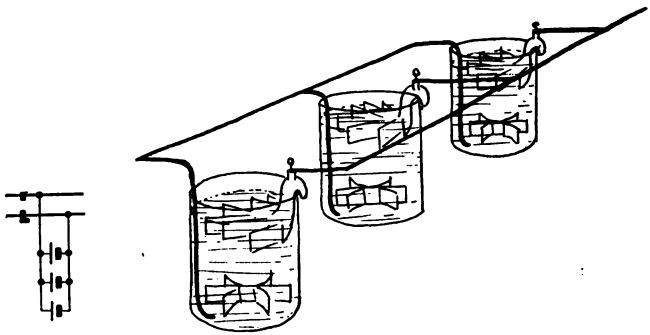


Figure 60—Three Cells in Parallel.

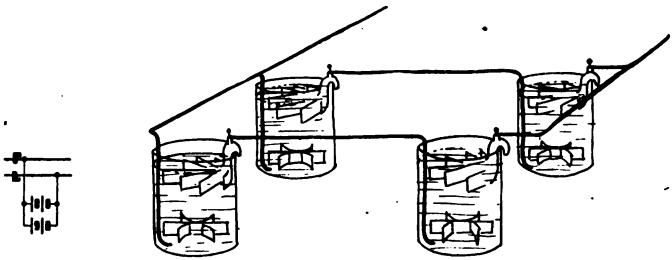


Figure 61—Four Cells in Multiple Series.

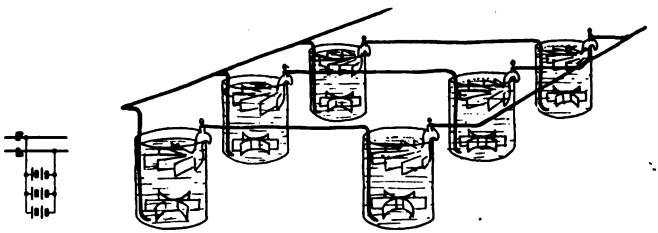


Figure 62—Six Cells in Multiple Series.

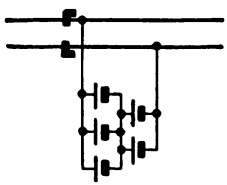


Figure 63.

We all know that if we have a column of water a foot high in a jar (see Figure 64A) and put a faucet in the bottom of the jar, we can get a certain pressure on the faucet because of the column of water one foot high above it. Now, if we take a jar which is two feet high and fill it full of water, the pressure at the bottom will be twice that in the jar one foot high,

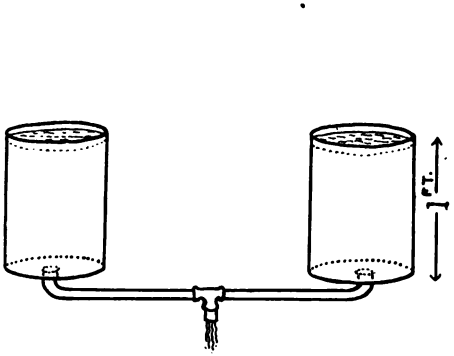


Figure 64A.

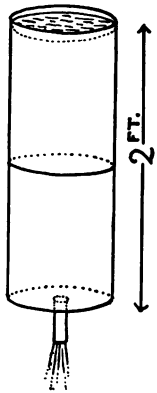


Figure 64B.

because it has a column of water two feet high. The diameter of the jar has nothing to do with the pressure. There is no more pressure in a faucet in the bottom of a tank fifteen feet in diameter with one foot of water in it, than there is on a faucet in the bottom of a jar one foot in diameter with one foot of water in it. The pressure *per square inch* on the bottom is what governs the force of the water in the faucet.

If we take two jars, each a foot high, and set them side by side, it is evident that we will only have a pressure corresponding to one foot of water; so that if we set them side by side and connect them, we will

only have one-half the pressure we have in the jar which is twice as high, the pressure of the water at the bottom of the jar depending entirely upon the height of the water above it. The two jars side by side in Figure 64A act upon the same principle as two battery cells connected in parallel, and the two jars on top of each other act upon the same principle as cells in series.

Figure 59 shows two battery cells for a track circuit connected in parallel. The voltage will be practically the same as the voltage of one cell. It should be understood that the current output of these various battery cell arrangements will not be exactly as indicated because the internal resistance of the different arrangements varies. Where cells are placed in parallel, the internal resistance of the battery is reduced in proportion to the number of cells. With two cells in parallel, the internal resistance is decreased to one-half, while with three cells in parallel, the internal resistance is decreased to one-third, etc. But where cells are placed in series, the internal resistance is increased according to the number of cells. For instance, with two cells it is twice as much, with three cells three times as much, etc.

Figure 62 shows six cells—each pair connected in series, and the three pairs connected in multiple. Figure 63 shows five cells of battery—three cells connected in parallel, two cells connected in parallel, and the two groups connected in series. Figure 61 is similar to two cells connected in series except for the fact that there are two pairs of cells, each being connected in series and the two pairs then being wired in parallel.

Figure 60 shows three single cells of battery connected in parallel.

Where only a low voltage is required, two cells in series may "fill the bill," and Figure 61 and Figure 62 indicate the way the capacity or life of the battery may be increased while the voltage remains almost constant, being increased slightly because of the decreased internal resistance.

Figure 59 indicates a way of increasing the voltage almost to double that of a single cell. Figures 61 and 62 show ways of increasing the capacity or life of the battery while increasing the voltage of current output but slightly.

Mechanical Features To Be Considered—There are certain mechanical features which must be considered in the battery arrangement. For instance, in cells in series it is plain that if the connections on a single cell should break, or if the cell itself should break, the current would be interrupted and there would be a complete failure of the track circuit, which would result in a "stop" indication and hence in delays to trains.

In Figure 59 one battery cell may be broken or have poor connections and the other cell will still continue to operate the track circuit. The same is true of the other arrangements shown, and the degree of protection against poor connections and broken cells is increased in proportion to the number of parallel units used.

The proper arrangement for the cells of a battery depends upon the particular conditions in the track circuit where the cells are used. The current output

of the above arrangements is as follows: Starting with Figure 59, which of course gives the smallest current, the output increases in the following order: Figure 62, Figure 60, Figure 61 and Figure 59. Knowing these facts, it is possible to arrange the number of cells available to accomplish the best results on each track circuit. The cells should be so arranged as to give the greatest possible efficiency consistent with economy in the number used.

Figure 65—Columbia Primary Cell.

Gravity Battery—An ordinary gravity battery cell consists of a jar in which are placed a positive copper element and a negative zinc element, as shown in Figure 59. Water and a chemical which is commonly called blue vitriol, but which consists of zinc and copper sulphate, are added. The zinc (see Figure 59), in the form of a crowfoot, is centered in the top of the jar, and the copper, which may be of various shapes, rests on the bottom.

Caustic Soda Cells—The Signal Division of the A. R. A. has adopted standard specifications for

caustic soda or potash signal cells, in which the renewal element consists of a sealed can of caustic soda, a sealed bottle of mineral oil, and assembled elements, with connecting wire and rigidly connected suspension bolts.

Columbia Track Battery—The Columbia track battery is a primary caustic soda cell, having flaky copper oxide as a positive element, loosely placed on a tin disc to which is riveted the wire for connection to the external circuit. The negative element consists of amalgamated zinc, is circular in form, and is supported

Figure 66—Edison Primary Cell.

in the center of the jar by means of wires hooked over the edge. The internal resistance of this cell is high, but not as high as that of the gravity cell. These cells will not freeze because of the character of the chemical solution in them, and they do not require cleaning or attention from the time they are put into service until the elements are exhausted.

Edison B. S. C. O. Cells—The elements in the Edison B. S. C. O. primary cell are made of amalgamated zinc and compressed copper oxide. Each cell contains two zinc plates and one copper plate. The

electrolyte or solution consists of caustic soda and water, and the action of the cell gradually dissolves the zinc plates and converts the copper oxide into a plate of pure copper.

When entirely exhausted, the copper oxide will all have been changed to copper; and the proportion of copper oxide to pure copper gives an idea of how much life there is left in the cell.

Waterbury Cells—Waterbury primary battery cells are of the Lalande type. The active materials consist

Figure 67—Waterbury Primary Cell.

of amalgamated zinc (negative) and oxide of copper (positive), and an electrolyte of sodium hydrox and water.

Figure 67 is the separate cylinder type of Waterbury primary cell. The zinc element, which is cylindrical in form, and the copper oxide cylinder, which goes inside of the zinc element, are illustrated at the right, as is also the method of suspending the elements from the cover.

When this type of Waterbury primary cell is discharged, the zinc cylinder is reduced to a thin shell and the upper and lower edges begin to crumble away. The extent of these actions indicates to what degree the capacity of the cell has been exhausted.

In renewing the cells, the exhausted zinc and copper oxide elements are detached from the cover, the old solution is emptied from the jar, and new zinc and copper elements are attached to the cover after the jar, the cover and the nuts have been cleaned. The cell can then be set up according to the directions for new cells.

CHAPTER X

STORAGE BATTERIES

STORAGE batteries are of two general types. One, called the lead sulphuric acid type, has electrodes of peroxide of lead and finely divided sulphuric acid. There are two general subdivisions under which all storage batteries of the lead sulphuric acid type may be divided: (1) Planté and (2) Pasted (Faure). All lead batteries whose active material is obtained by means of chemical or electro-chemical action upon lead elements, and whose electrolyte is a solution of sulphuric acid and water, are of the Planté type. Those batteries in which the active material consists of a lead oxide paste, which is applied to a grid, are of the Pasted type. In the Planté (lead sulphuric acid) cells, the electrodes consist of (1) peroxide of lead and (2) finely divided metallic lead, both of which are supported on lead supports in an electrolyte of diluted sulphuric acid.

Each cell of the Planté or lead sulphuric type of battery has a voltage, or electro-motive force, of approximately two volts, and an ampere hour capacity depending upon the number and size of its plates.

Storage batteries are used extensively for electric interlocking plants, for operating draw bridges, for signal lighting, for track circuits, and for operating bells, electric locks and signals. They are either charged by a portable charging outfit, or the cells are transported to a stationary charging outfit and there renewed. In the meantime, exchanged cells are used to take the place of those under charge.

When storage battery is used in operating track circuits, it is necessary to insert a resistance in one or both battery leads to restrict the flow of current and prevent the batteries from becoming exhausted by the passage of a single train, or from being injured by overdischarge. As mentioned in the preceding chapter, with primary battery the internal resistance is high enough to prevent this.

Installation and Operation of Storage Batteries in Signal Service

The Railway Signal Association, in 1908, included instructions for installing, operating and caring for storage battery, and these instructions are given complete below:

Storage batteries are used in connection with interlocking and block signals.

In interlocking plants the batteries are permanently located at the working points and charged from a central source of power.

In automatic work, batteries are used in three ways:

1. Battery permanently located at working point and charged from transmission line.

2. Battery permanently located at working point and charged from primary cells.

3. Battery located at working point on discharge only, and removed to power source for recharge.

The batteries for interlocking plants, and applications No. 1 and No. 2 for block signals, are never moved and are termed "stationary batteries."

The batteries for class No. 3 in block signals require a battery which can be readily handled and moved from place to place, and therefore are termed "portable batteries."

Installation of Stationary Batteries—The battery should be in a space by itself, as the acid fumes given off during the charge are of a corrosive nature. This space should be well ventilated, well lighted, and as dry as possible. If the space is specially constructed, it should contain no metal work other than lead. If this is not possible, then such metal parts should be protected by at least two coats of acid-proof paint. The floors of a large battery room should be preferably of vitrified brick, jointed with pitch.

The batteries should be placed in rooms of uniform temperature, preferably 70 deg. F. Low temperature does not injure a battery, but lowers its capacity approximately one-half per cent per degree. Excessively high temperature shortens the life of the plates.

If the batteries are in glass jars and not of the two-plate type, the following directions should be observed in installing them:

Batteries up to 400 a. h. capacity shall be placed in glass jars. All batteries shall be for an eight-hour rate of discharge at 70 deg. F.

For a battery of greater capacity than 400 a. h., wooden tanks shall be required and should be covered by special specifications.

In batteries of a large number of cells, such as in interlocking plants, substantial wood racks should be provided to support the cells. These racks should preferably be made of long-leaf yellow pine with non-corrosive fastenings, and thoroughly protected by at least two coats of acid-proof paint. The cells should be arranged transversely, and the layout of cells should be such that each cell is accessible for inspection, and that there is sufficient

head room over each cell to remove the element without moving the jar.

Each jar is set in a tray which has been evenly filled with fine dry bar sand, the trays resting on suitable insulators.

When placing the positive and negative groups into the jars, see that the direction of the lugs is relatively the same in each case, so that a positive lug of one cell adjoins and is connected to a negative lug of the next cell, and so on throughout the battery. This insures the proper polarity throughout the battery, bringing a positive lug at one free end and a negative at the other.

Before bolting the battery lugs together, they should be well scraped at the point of contact to insure good conductivity and low resistance of the circuit. The connector studs should be covered with vaseline before being screwed up, and the entire connections covered with vaseline or suitable paint.

Before putting the electrolyte into the cells, the circuits connecting the battery with the charging source must be completed, care being taken to have the positive pole of the charging source connected with the positive end of the battery, and so with the negative poles. The electrolyte should cover the top of plates by one-half inch.

Electrolyte: The electrolyte shall be of a quality and specific gravity approved by the battery manufacturer.

If it is not practicable to obtain approved electrolyte, tests for the purity of the supply obtained should be made before it is used. Specifications for tests will be found under the heading, "Specifications for Tests for New Electrolyte."

Initial Charge: The initial charge should follow the

manufacturer's instructions. The charge should be started promptly as soon as all the cells are filled with electrolyte, and all connections made, usually at the normal rate, and continued at the same rate until both the specific gravity and voltage show no rise over a period of ten hours, and gas is being freely given off from all the plates. The positive plates will gas sometimes before the negatives. Generally, to meet these conditions, from forty-five to fifty-five hours' continuous charging at the normal rate will be required; and if the rate is less, the time required will be proportionately increased. In case the charge is interrupted, particularly during its earlier stages, or if it is not started as soon as the electrolyte is in the cells, the total charge required (in ampere hours) will be greater than if the charge is continuous and is started at once.

As a guide in following the progress of the charge, readings should be regularly taken and recorded. The gassing should also be watched, and if any cells are not gassing as much as the surrounding cells, they should be carefully examined and the cause of the trouble removed. The temperature of the electrolyte should be closely watched, and if it approaches 100 deg. F., the charging rate must be reduced or the charge temporarily stopped until the temperature lowers.

The specific gravity will fall after the electrolyte is added to the cells, and will then gradually rise as the charge progresses, until it is up to 1210 or thereabouts.

The voltage of each cell at the end of the charge will have risen to its maximum, and usually will be between 2.50 and 2.70 volts, and for this reason a fixed or definite voltage should not be aimed for.

If the specific gravity of any of the cells at the completion of the charge is below 1205 or above 1215, allowance being made for the temperature correction, it should be adjusted to within these limits, by removing and adding electrolyte if specific gravity is low, and adding pure water if the specific gravity is high, to again bring the surface at the proper height above the top of the plates.

It is of the utmost importance that the initial charge be complete in every respect.

NOTE: In the case of batteries charging from primary cells, if possible, the initial charge should be given at a place where direct current is available of sufficient voltage to carry through the charge at the normal rate (see general instructions), the cells then being transferred to their permanent position.

Two-Plate Cells: The general method of installation is the same as the above, with the following exceptions:

Each cell contains one positive and one negative, the positive of one jar being solidly connected by a lead strap to the negative plate of the adjoining jar, and consequently no connectors are required. At the ends of each row there is one free positive plate and one free negative plate, respectively, which constitute the positive and negative terminals of that row. Connections to these terminals are made with bolt connectors.

For the installation of very large batteries, where tanks are used, it is customary to support the tanks on a double tier of glass insulators. The plates are shipped separately and assembled one at a time in the tank and burned solidly to a heavy lead bus bar by means of a hydrogen flame. It is recommended, when installations of this kind are required, that the battery manufacturers

install the battery in accordance with their standard practice.

Installation of Portable Batteries—

Initial Charge: The initial charge should follow the manufacturer's instructions. If, as is the usual practice, the battery is shipped with the electrolyte (solution) in the cells, immediately upon receipt remove the vent plugs from each cell, and *if the electrolyte does not cover the plates,* add sufficient pure water until the plates are covered one-half an inch. Although the battery is fully charged before shipment, it is advisable to give it a five-hour charge at the normal rate, as given on the name plate.

If, however, the battery is shipped "dry," or without the electrolyte in the cells, and equipped with rubber separators, it should usually be put in service as follows: Fill the cells slowly with electrolyte of 1170 specific gravity (see note) until the plates are covered one-half inch, and then immediately start the charge at one-half normal rate, and continue until the voltage of each cell has ceased to rise and the cells have been gassing freely over a period of ten hours, and there is no further rise in the specific gravity over the same period. About seventy hours at one-half the normal charge rate will be required to complete the charge. If the rate is less than this, the time required will be proportionately increased.

If the temperature of the electrolyte rises to 110 deg. F. during the charge, the current should be reduced or stopped until it lowers. After the completion of the charge, adjust the specific gravity to between 1275 and 1300, with the electrolyte at the proper height (one-half inch above the plates).

NOTE: If the battery is assembled on the ground, and

wood separators are used, then the electrolyte used for filling should be of 1210 sp. gr. If rubber separators are used, the electrolyte used for filling should be 1710 sp. gr.

Routine Instructions for the Operation and Care of Storage Batteries in Interlocking Plants—

Pilot Cell: In each battery select a readily accessible cell, to be used in following the daily operation of the battery, by taking specific gravity readings of the electrolyte, as given below. Keep the level of the electrolyte of this cell at a fixed height, one-half inch above the top of the plates, by adding a small quantity of pure water each day. *This is extremely important.*

Charging: As a general rule, do not charge until the gravity of the pilot cell has fallen at least ten points (.010 sp. gr.) below the preceding overcharge maximum (see "Overcharge" below), the battery then being about one-third discharged.

In any case, charge as soon as possible after reaching either of the limits given below under "Discharging," or if for any reason a heavy discharge is expected.

Regular Charge: Charge at the normal rate of ..... amperes, or as near as possible, and continue until the gravity of the pilot cell has risen to three points below the maximum reached on the preceding overcharge, *when the charge should be stopped.* For example, if the maximum gravity on the overcharge is 1207, the gravity reached on regular charge should be 1204. The cells should be all gassing moderately.

Overcharge: Once every two weeks, on ....., prolong the regular charge until fifteen-minute readings of the gravity of the pilot cell and of the battery voltage, taken from the time the cells begin to gas, show no rise

on five successive readings, thus having been at a maximum for one hour.

NOTE: When the above method of overcharge is not practicable, the overcharge may be given every sixth charge, provided the battery receives an overcharge at least once a month. In following this method—i. e., where the overcharge is given at intervals longer than two weeks and not less frequently than once a month, the regular charge should be prolonged until one-half hour readings of the gravity of the pilot cell and of the battery voltage, taken from the time the cells begin to gas, show no rise on seven successive readings, thus having been at the maximum for three hours. The cells should all be gassing freely. The overcharge should be given whether the battery has been in regular use or not.

Charging in Series: If two or more batteries are charged together in series, care should be taken that each battery is cut out at the proper time. In other words, if one of the batteries discharges less than the other, it should not receive as much charge.

Discharging: Never allow the gravity of the pilot cell to fall more than about thirty points below the preceding overcharge maximum. As a rule, do not allow gravity to fall more than twenty points.

Never allow the voltage to go below 1.85 *volts per cell* when discharging at the normal rate (..... amperes). If the rate of discharge is less than the normal rate, the voltage should not be allowed to go so low.

Limiting voltage ..... cells ..... volts.

Never allow the battery to stand in a *completely discharged* condition.

Readings: Read and record the gravity of the pilot cell and battery voltage just before the start and the

end of every charge, together with the temperature of the electrolyte.

Properly to compare the gravity readings, they should be corrected to standard temperature, 70 deg. F., as follows: Add one point (.001) for every three degrees above 70 deg. F., and subtract one point (.001) for every three degrees below 70 deg. F.

Once every two weeks, after the end of the charge preceding the overcharge, read and record the gravity of each cell in the battery.

Inspection: Carefully inspect each cell on the day before the overcharge, using a lamp on an extension cord for the purpose. Examine between the plates and hanging lugs to make sure that they are not touching, and also make a careful note of any peculiarity in color, etc., of the plates.

Use a strip of wood or hard rubber in removing short circuits. *Never use metal.*

Towards the end of the charge preceding the overcharge, note any irregularity of gassing among the cells. Any which are slow in gassing should be investigated.

Indications of Trouble: Falling off in specific gravity or voltage relative to the rest of the cells.

Lack of or slower gassing on overcharge, as compared with surrounding cells.

Color of plates markedly lighter or darker than in surrounding cells, except that sides of plates facing glass may vary considerably.

In case of any of the above symptoms being found, examine carefully for cause, and *remove at once.*

Report trouble of any description at once to .....

Broken Jars: If a jar should break and there is no other to take its place, so that the plates will have to

remain out of service for some time, keep the negatives wet in a tub of water and allow the positives to dry. Connect into circuit again just before a charge, so that the plates will receive the benefit of the charge.

Other Important Points: The plates must always be kept covered with electrolyte. Use only pure water, preferably distilled, to replace evaporation.

Never add electrolyte except under the conditions explained in the general instructions.

Never allow the sediment to get up to the bottom of the plates. Remove when the clearance has reached one-half an inch.

Ventilate the room freely, especially when charging.

Never bring an exposed flame near the battery when charging.

Never allow metals or impurities of any kind to get into the cells. If this has happened, remove at once, wash the plates and replace the electrolyte.

Fill out the report sheets regularly.

Read the general instructions carefully.

Routine Instructions for the Operation and Care of Storage Batteries in Block Signal Service, Central Charging Plant—

Charging: When to charge: Unnecessarily frequent charging should be avoided; but to insure a reserve in case of emergency, it is advisable not to take out on discharge more than one-third capacity, this being indicated by the fall of the specific gravity of the electrolyte. The fall in gravity is in proportion to the ampere hours discharged, and for a discharge equal to one-third capacity is approximately ten points (.010 specific gravity). How frequently each circuit or series of batteries should be

charged will be governed by the battery in the circuit having the greatest average amount of discharge. Having determined which battery first shows a drop in gravity from full charge to the regular working limit (not exceeding ten points), charge often enough to prevent the gravity of the battery from falling below this limit.

Regular Charge: Charge at an average rate of ..... amperes for ..... hours (this being the time required to bring the battery having the greatest discharge up to full charge, as indicated by the specific gravity and voltage ceasing to rise).

Overcharge: Once every two weeks prolong the regular charge for three hours.

Discharging: As a general rule, do not continue the discharge after the gravity of the battery receiving the most discharge has fallen more than ten points from maximum. Never, however, except in case of emergency, allow the gravity to fall more than thirty points from maximum, or the voltage below 1.85 volts per cell, when discharging at the normal rate (..... amperes). If the rate of discharge is less than the normal rate, the voltage should not be allowed to go so low.

Readings: Once a month, on the day before the overcharge, read and record the gravity of each cell of each battery on the circuit, together with the average temperature of the electrolyte.

Properly to compare the gravity readings, they should be corrected to standard temperature, 70 deg. F., as follows: Add one point (.001) for every three degrees above 70 deg. F., and subtract one point (.001) for every three degrees below 70 deg. F.

Inspection: Carefully inspect each cell once a month, on the day before the overcharge. Examine between the

plates and hanging lugs to make sure that they are not touching, and also make a careful note of any peculiarity in color, etc., of the plates. Always use a strip of wood or hard rubber in removing short circuits. *Never use metal.*

In case a battery or individual cell is found to be in poor condition, due to overdischarge, short circuits, impurities in the electrolyte or sediment touching the plates, it may be well or advisable to remove it to the charging plant for treatment, first substituting in its place a fully charged battery or cell, or else a portable set kept for the purpose. (For treatment of low cells, see "General Instructions.")

The instructions under the headings, "Indications of Trouble," "Broken Jars," and "Other Important Points," are the same as those for storage batteries in interlocking plants, given on a preceding page.

Routine Instructions for the Operation and Care of Batteries in Signal Service—Charging from Primary Cell—

Operation: For regular operation, sufficient primary cells (connected either in single series or in multiple series) should be installed to maintain the storage cells at approximately a constant state of charge, as shown by the specific gravity of the electrolyte remaining at about the same point. If the gravity falls off, there is a lack of sufficient charge. The voltage per cell should average between 2.08 and 2.12 volts. A higher average than this shows that the battery is receiving too much charge, which is also indicated by a constant slight gassing. A lower average voltage indicates insufficient charge, resulting in the falling off in gravity referred to above.

The gravity of the cells operating as above, in a fully charged state, should be between 1205 and 1215 at normal temperature (70 deg. F.), with the electrolyte one-half an inch above the plates. Should there be an unusual drop in the gravity—say from ten to fifteen points (.010 to .015 sp. gr.) below the normal, or of the voltage below 1.95 volts per cell, the cause should be investigated.

Readings: At intervals, not exceeding one month, read and record, on a suitable form, the gravity and voltage of each storage cell, together with the temperature of the electrolyte, and by means of a portable ammeter read and record the charging current delivered from the primary cells.

Properly to compare the gravity readings, they should be corrected to standard temperature, 70 deg. F., as follows: Add one point (.001) for every three degrees above 70 deg. F., and subtract one point (.001) for every three degrees below 70 deg. F.

Inspection: At the time the readings are taken, inspect each storage cell, examining between the plates and hanging lugs to make sure that they are not touching, and also make a careful note of any peculiarity in color, etc., of the plates.

Always use a strip of wood or hard rubber in removing short circuits. *Never use metal.*

See that the cell connections are clean and tight.

In case a battery or individual cell is found to be in poor condition, due to overdischarge, short circuits, impurities in the electrolyte or sediment touching the plates, it will be advisable to remove it to some central point where it can be treated to better advantage, substituting in its place a fully charged battery, or else a portable set kept for the purpose.

The instructions under the headings, "Indications of Trouble," "Broken Jars," and "Other Important Points," are the same as those for storage batteries in interlocking plants, given on a preceding page.

Routine Instructions for the Operation and Care of Portable Storage Batteries in Signal Service—

When to Charge: Charge each battery frequently enough to keep the specific gravity of the electrolyte from falling more than eighty points (.080 sp. gr.) below what it read when fully charged, the battery then being about two-thirds discharged. For instance, if the gravity when fully charged is 1300, do not allow it to fall below 1220.

In any case, the battery should be charged once a month, whether it is in use or not. If the battery has been idle, it should be charged before being put into service again.

Charging: Remove the vent plugs before charging. Charge at the rate of ..... amperes. After the cells begin to gas, read and record the gravity and voltage of each cell every two hours, continuing to charge until three of these readings are alike.

If the time for charging is limited, the charge may be started at ..... amperes, reducing the rate to ..... amperes when the cells begin to gas, and continuing the charge until four readings of the gravity and voltage, taken every two hours, are alike.

The cells should all be gassing freely at the end of charge.

Do not allow the temperature of the electrolyte to exceed 100 deg. F. while charging. If it tends to do so, reduce the charging rate or discontinue charging until it lowers.

Discharging: Never, except in case of emergency,

allow the gravity to fall more than eighty points below what it read when last charged.

Readings: Record, on a suitable form, the specific gravity of each battery before starting the charge and at its completion, including, with the latter, voltage readings taken with the charging current flowing.

Electrolyte: Replacing evaporation: Keep the plates well covered with electrolyte and use only pure water to replace evaporation. Never use electrolyte for this purpose.

Adjusting Specific Gravity: The gravity of the electrolyte should, with the cells fully charged, be between 1270 and 1300, and unless actually lost through spilling or a leaky jar, it should not need frequent adjustment. If, at the end of charge, the gravity does not rise to its normal value, the battery should be carefully inspected for short circuits or other troubles, and if any are found, they should be removed, and the charge continued until gravity ceases to rise. If no short circuits or other troubles are found, the gravity should be brought up to 1300 by replacing some of the electrolyte with electrolyte having a higher gravity. Should it read above 1300, it should be reduced by taking out a little electrolyte and replacing it with pure water. To accomplish the above result, it will generally be found more convenient to pour out all the old electrolyte and replace it at once with new electrolyte of the proper gravity.

General Care: After a battery has been charged, the outside of the case and tops of jars should be carefully cleaned. The connectors should be taken apart and washed in a solution of bi-carbonate of soda and water and rinsed with water and, when dry, well oiled.

The case should also be well oiled before the battery

is sent out. Oil should never be allowed to come in contact with soft rubber.

Once each year each battery should be taken apart, the sediment removed from the bottom of the jar, and the plates and separators lightly washed before being replaced. Any broken or damaged parts should be renewed. Do not allow the plates to dry. The old electrolyte can be used again, adjusting it to the proper gravity at the completion of the charge, following the cleaning. Every second cleaning it is advisable to use new electrolyte.

Indications of Trouble: Falling off in specific gravity or voltage relative to the rest of the cells.

Lack of or slower gassing on overcharge, as compared with surrounding cells.

Color of plates markedly lighter or darker than in surrounding cells, except that sides of plates facing glass may vary considerably.

In case of any of the above symptoms being found, examine carefully for cause and remove at once.

Important Points: Always fully charge.

The plates must always be kept covered with electrolyte.

Use only pure water, preferably distilled, to replace evaporation.

Never add electrolyte except under the conditions explained above.

Never allow the sediment to get up to the bottom of the plates.

Ventilate the room freely when charging.

Never bring an exposed flame near the batteries when charging.

Never allow metals or impurities of any kind to get into the cells. If this has happened, remove at once,

wash the plates and replace the electrolyte.

Fill out the record sheets regularly.

Specifications and Tests for New Electrolyte—

Color: The sample should be absolutely clear and colorless, showing no dark color due to organic matter. A small amount of lead sulphate sometimes present, which shows as a white sediment, will do no harm.

Odor: Shake up a closed flask or bottle partially filled with the electrolyte, and then uncork and note whether there is any odor. Sometimes sulphurous or nitric acid can be detected in this manner, and the further testing be very much shortened.

Chlorine: To a sample of the electrolyte in a test tube add a few drops of nitric acid, and then a little silver nitrate solution. Note the appearance when cold, and then boil. The sample should remain perfectly clear when cold, and show only a slight, if any, turbidity on boiling.

Iron: To a few cc. of the sample in a test tube add weak potassium permanganate solution, drop by drop, until a faint pink color is permanent. Then add a little ammonium (or potassium sulphocyanate solution), when the presence of iron will be indicated by a red color. It is almost impossible to obtain acid which will not show a faint color by this test, as it is very delicate; but if the color is at all deep, the acid should be rejected or else submitted for a quantitative analysis.

Oxides of Nitrogen: Take about five cc. of diphenylamin solution (one-half gram to 100 cc. c. p. sulphuric acid, 1.84 sp. gr., and 20 cc. distilled water) in a test tube, and carefully pour in about an equal volume of the electrolyte to be tested. The presence of oxides of nitro-

gen, or nitric acid, is shown by a deep blue color at the intersection of the two liquids.

Heavy Metals (Platinum, Copper, etc.), Arsenic, Selenium and Sulphurous Acid: Treat about 100 cc. with hydrogen sulphide until thoroughly saturated. The solution should remain perfectly clear and show no color or precipitate. A negative result shows absence of heavy metals, also arsenic, selenium and sulphurous acid. A very slight separation of sulphur may be neglected; but if the solution becomes quite turbid, sulphurous acid should be tested for as follows: Place some of the electrolyte in a small narrow-necked flask and add some finely divided pure zinc. Test the gas evolved with filter paper saturated with lead acetate solution. If the paper turns brown or black, sulphurous acid is present.

NOTE: It should be understood that these tests are for new electrolyte which has not previously been used in a battery. If the results obtained from any of the several tests are such as to allow of any uncertainty regarding the suitability of the electrolyte, a sample (at least eight ounces) should be submitted to the battery manufacturer; likewise any samples of old electrolyte from cells in which the presence of impurities is suspected.

CHAPTER XI

RELAYS

THE Signal Dictionary defines a relay as "an electro-magnet designed to repeat the effects of one electric current in a second circuit." In a track circuit relay which is adjusted to operate on the passage of a weak current, the attracting or dropping of the armature opens a strong local circuit which operates the signal. A relay which has a number of contacts may control a number of secondary circuits. When the armature of a relay is "picked up," the front contacts are closed, and when the current is shunted out of the relay, the armature drops, closing the back contacts. The armature drops away from its pole pieces by gravity when the attraction is withdrawn.

There are a number of different kinds of relays, among which are the ordinary neutral relay, the polarized relay, the interlocking relay, and the mercury contact relay, which are direct current relays, and the vane relay, the frequency relay and the polyphase relay, which are alternating current relays.

Neutral Relay—The "neutral relay" is the name given to the ordinary D. C. relay with which we are familiar. It is a direct current electro-magnetic relay whose armature is attracted to the pole pieces whenever there is current in the relay coil, regardless of the direction of the current.

In Figure 68 No. 13 is the coil through which the electric current passes when the relay is energized; and when current is passing through the coils, pole

pieces No. 5 attract armature No. 6. Armature stops, made of bone, brass or phosphorus bronze, are placed in the ends of the pole pieces to overcome residual magnetism and to prevent the armature from sticking.

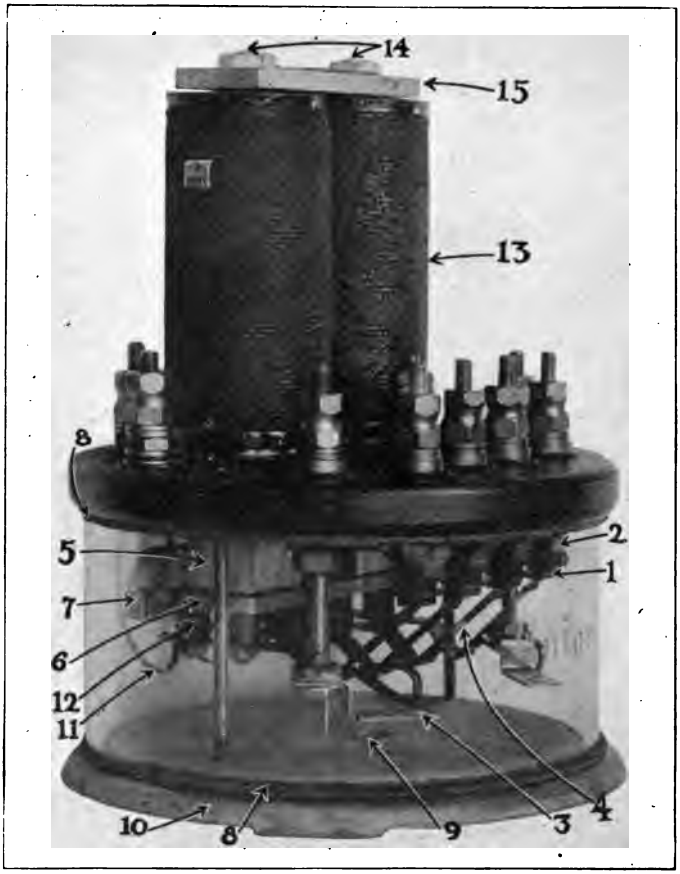


Figure 68—Neutral Relay.

As shown, the relay is de-energized—that is, no current is flowing in the coil; and armature No. 6 has dropped down, carrying with it front contact fingers No. 4 and breaking the front contact, back contact No. 3 at the same time having made connection by dropping onto a shelf of the binding post.

When the relay is energized—that is, when current is flowing through the coil—armature No. 6 will be attracted to pole pieces No. 5 and will thus raise contact fingers No. 4, so that the contact fingers will be lifted against contact point No. 1 on the binding post. The contact at No. 1 is the front contact, and that at No. 3 is the back contact. Contact points No. 3 and No. 1 are made of platinum, and the front contact points are generally cut into three parts, so that a better contact may be assured in case the entire point does not make a good connection.

It will be noted that when the relay is de-energized, as shown in this illustration, the current is passing from binding post through the contact fingers and back contact No. 3 to the other binding post.

When coil No. 13 is energized and the relay armature is picked up, the current will go from binding post through the fingers and to opposite binding post. Thus the circuits attached to these binding posts are made or broken as the armature falls or rises. Platinum is used on contact points because it gives a better electrical connection.

The relay is said to be closed when it is energized, when armature No. 6 is attracted up against pole

pieces at No. 5, and when a connection is made at front contact No. 1. When the armature has dropped away from pole pieces and contact has been made at No. 3, the relay is said to be open.

Polarized Relay—The polarized relay is so named because its polarized armature is a permanently magnetized piece of metal. We have seen in the chapter

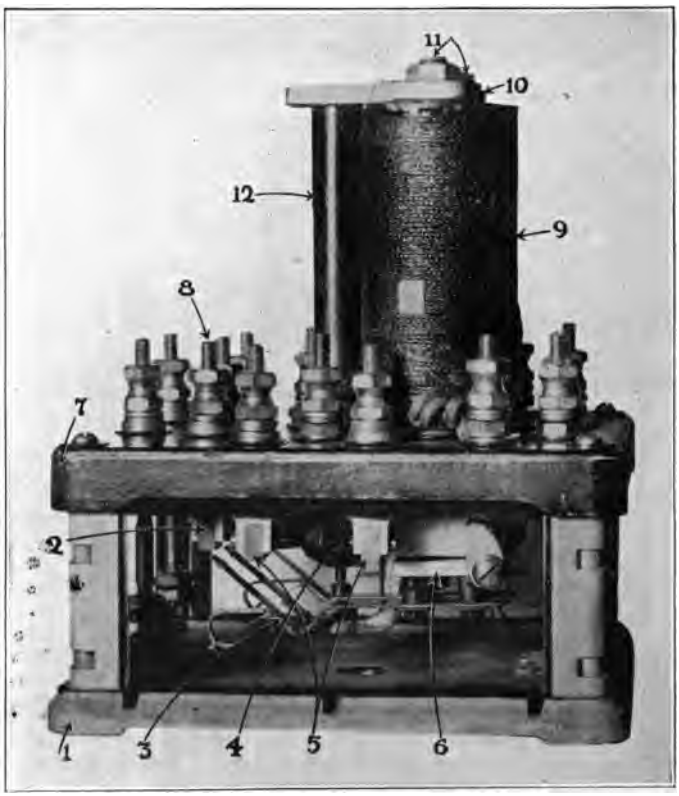


Figure 69—Polarized Relay.

on magnetism that like poles of two magnets **repel** each other and unlike poles attract each other. With the polarized armature, when the current is flowing through the coil of the relay in one direction, what we may call positive magnetism is established; and when the current is going through in the opposite direction, negative magnetism is established. In one case the end of the armature is attracted to one pole, and in the other case the armature is attracted to the opposite pole.

The ordinary relay armature is of soft iron, which retains magnetism but slightly, and which is therefore attracted by either the positive or the negative mag-

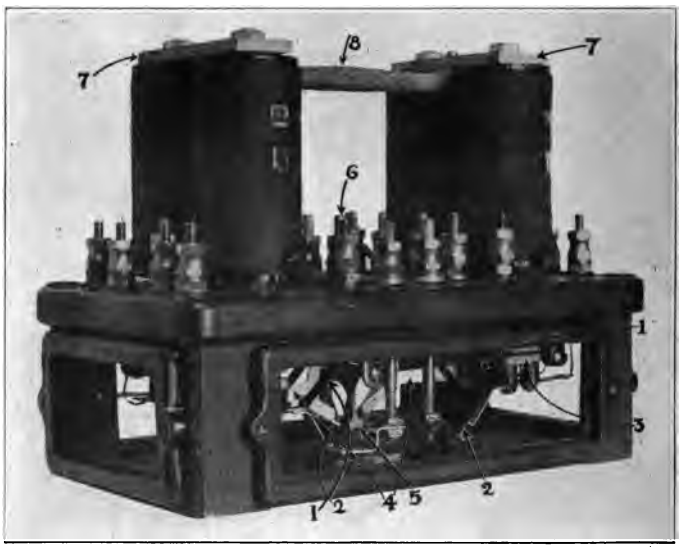


Figure 70—Interlocking Relay.

netism set up by the current flowing in either direction.

Interlocking Relay—The interlocking relay consists of two relays mounted upon a single base and so arranged that the armature of one can be made to interlock or lock the armature of the other. This relay is used where it is desirable to lock one armature in position when the other armature is in a certain position.

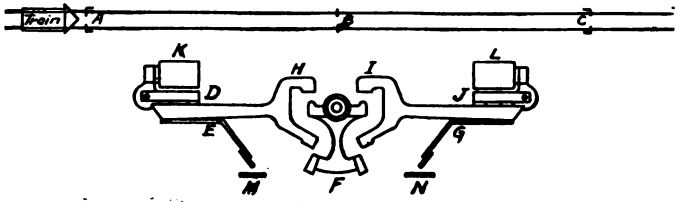


Figure 71.

Figure 71 illustrates the normal condition of an interlocking relay when the coils are energized with the armatures "picked up" and the controlling track sections unoccupied. "K" and "L" are the magnet heads of the two electro-magnets of the relay. "D" and "J" are the armature bars which are hinged to "K" and "L" and carry the contact arms "E" and "G," which are insulated from "D" and "J." "H" and "I" represent the interlocking arms, carried by "D" and "J," and engage the locking pawl "F" under certain conditions hereafter noted. "M" and "N" are graphite to platinum or platinum to platinum contacts connected to binding posts of the relay, to which external wires are fastened by thumb and jam nuts. A train is represented approaching the track section "AB" at "A."

Figure 72 illustrates the condition of the parts

of the relay above noted after a train has entered the track section "AB" and is continuing on toward "B."

The coils of magnet "K" are de-energized and the armature "D" has fallen away from the magnet head and made back contact with the post "M." The inter-

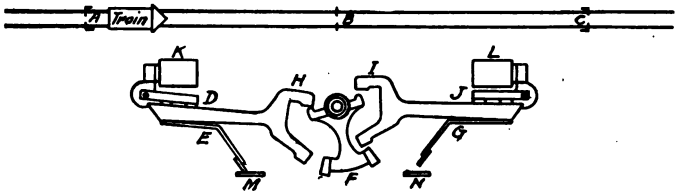


Figure 72.

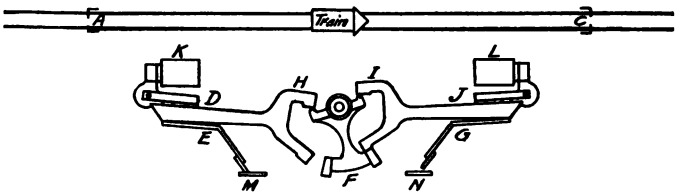


Figure 73.

locking arm "H" in falling throws locking pawl "F" to the position shown, thereby providing for the interference of this pawl and interlocking arm "I," preparatory to the condition shown in Figure 73.

Figure 73 shows this condition as the train enters the section "BC" and short circuits the coils of "L." The train at this instant will hold both relays open; but the armature "J" cannot fall far enough to make back contact between "H" and "G" since the interlocking arm "I" has caught on the pawl "F." This condition will remain until the train clears section "AB," as shown by Figure 74.

In Figure 74 the train has passed out of section "AB" entirely, in consequence of which the armature "D" picks up and opens the contact between "M" and "E," thereby breaking the local circuit passing through "M" and "E." If it is a bell circuit, the bell will stop ringing. The armature "J" remains down and locked as heretofore shown.

As the train clears the section "BC," the armature "J" will rise and the relay will be in its normal condition, as shown by Figure 75.

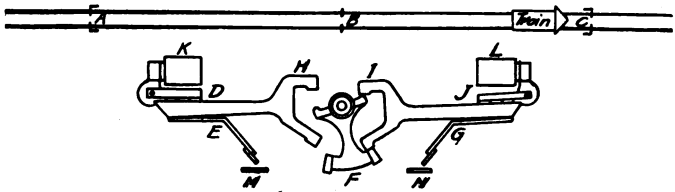


Figure 74.

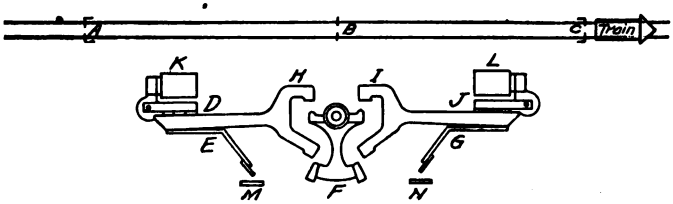


Figure 75.

A train movement from "C" towards "A" will operate the relay in a similar manner, but the closed local circuit will be through the contact "NG," the interlocking arm "H" being locked by the pawl "F."

Interlocking relays are chiefly used to control crossing alarm bells, etc. They are seldom used as part of an automatic block system owing to the nature of their construction. When there is a crossing-bell

installation in automatic territory, the best practice is to control the interlocking relay from adjacent track relay contacts.

Mercury Contact Relay—The mercury contact relay is one in which the armature makes a contact through mercury instead of through the ordinary materials used for contact.

Slow Releasing Relay—A slow releasing relay (D. C.) is used where it is desired to have the armature held up for a short time while the current is being changed, as in a polarized track circuit.

In this type of relay, copper tubes, around which insulated copper wires are wound, are placed over the iron cores. A secondary electric current is produced in these copper sleeves; and when the current is shorted out of the primary coil of the relay, the secondary current in the copper sleeves holds up the armature for a short time, five to eight seconds usually being sufficient.

Differential Relay—A differential relay (D. C.) consists of a relay with two sets of coils, one having a higher resistance than the other. The armature is placed between the two coils and is attracted to the coil which exerts the greater attracting force.

Compound Wound Relay—A compound wound relay (D. C.) is a relay in which the coils are wound as two separate units, connected in such a way that when the armature is down, a greater number of ampere turns are effective than is the case when it is raised. In the former case, the entire number of windings on the coils are in circuit, and in the latter case, only part of the ampere turns are in the circuit.

The relay is so arranged that the stronger current is used to attract the armature, but the weaker current is used to retain it. The purpose of the compound wound relay is to save energy after the relay is closed, less current being necessary to hold the armature up than is required to pick it up.

Solenoid Relay—The solenoid relay (D. C.) is based upon the principle of a solenoid, which consists of a coil of wire in which an iron core is inserted, the core being movable endwise. This movable iron core will be drawn inward by magnetic attraction. It may be withdrawn by a spring, but it is usually so arranged that it will drop down by gravity. This movement of the core is used to make and break the relay contacts.

Construction of Relay Coils—The coils of relays are protected by lightning arresters. If lightning should get into the coils, it would be a case of installing a new relay. The wire of which relay coils are wound is usually double-cotton covered, and after the coils are wound, they are impregnated in an insulating compound which eliminates all moisture and affords high insulation between the windings.

Alternating Current Relay—The alternating current relay is a relay designed to respond to and operate only on alternating current. It will operate only on alternating current of the frequency for which it was designed, and it is not affected by direct current.

Frequency Relay—The frequency relay is a type of alternating current relay which operates only on a certain frequency. The frequency is the number of cycles or alternations per second in an alternating

current. The frequencies most commonly used in commercial work are 25 cycles and 60 cycles per second. A frequency relay so made that it will operate on 60-cycle current will be unaffected by alternating current of 25 cycles or any other number of cycles under 30.

On an electric traction having a propulsion current of 25 cycles, the signaling current (in the U. S.) would be made 60-cycle, and a frequency track relay designed to operate on 60-cycle current would be provided.

Polyphase Relay—A polyphase relay, as its name implies, requires more than one phase to operate it. For example, an A. C. track relay has a local phase (110 or 55 volts) and a track phase (about 5 to 10 volts). The difference in phase produces torque. A line relay is usually split phase.

Vane Relay—The vane relay is a type of alternating current relay in which a light metal disc, or vane, either solid or perforated with radial slots, is caused to move between the pole pieces of a magnet to close the contacts when the windings are energized, or to open the contacts when the windings are de-energized. The movement of the vane in this relay is similar to the movement of the watt-meter vane.

Pick-Up and Drop-Away Points—The pick-up point of a relay is the current required in its coils to pick up its armature. The drop-away point of a relay is the point at which the armature is released when the current is reduced.

It is plainly evident that if we increase the air gap between the armature and the pole pieces, it will require a greater amount of current to raise the arma-

ture, because the magnetism is strongest close to the pole pieces and decreases as the distance from the pole pieces increases. Thus if the air gap between the armature and the pole pieces is increased, the pick-up point will be raised, and if the air gap is decreased, the pick-up point will be lowered.

In some cases the pick-up or drop-away points are adjusted by increasing or decreasing the tension of the spring contact fingers.

Testing—In Figure 76 is illustrated an adjustable resistance coil which is employed in testing relays for their pick-up and drop-away points. It is simply

Figure 76—Adjustable Resistance Coil.

necessary, with this adjustable resistance coil, to connect the wires of the current to the binding posts, and the value of the resistance is altered by moving the contacting slide to various positions. The resistance of a circuit can be varied by the fraction of an ohm with this instrument.

In Figure 77 is shown a diagram of this resistance in the circuit. Note that the current starts from the

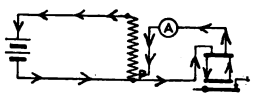


Figure 77.

positive side of the battery, goes through the relay, and then must pass through part of the resistance coil before it goes back to the battery.

The sliding contact slide in Figure 76 is equivalent to moving point "P" up higher on the coil (see Figure 77); and the higher this point, the less coil there is in series with the circuit. Point "P" is therefore moved up until the relay attracts its armature, and then the resistance is read upon the scale.

CHAPTER XII

ALTERNATING CURRENT SIGNALING

ONLY one kind of current can be obtained from a battery—direct current. On the other hand, we may obtain either direct current or alternating current from an electric current generator.

It is not economical to transmit direct current long distances because a great deal of the power represented in the circuit is lost in the resistance of the line wires. This is not the case with alternating current. It can be transmitted long distances without anywhere near the loss of power which occurs with direct current because of the ease of transforming alternating current to a higher voltage and then reducing it again.

The use of direct current in signaling has other drawbacks. Practically any direct current will have some effect upon direct current instruments and apparatus. Thus there is always more danger of foreign currents with a direct current signaling system than with an alternating current signaling system, because with the latter system the relays and other instruments may be so designed that neither direct current nor any other alternating current but the one particular kind will operate them.

The main difference of power supply between direct current and alternating current signaling systems is that direct current is furnished by batteries, while alternating current is furnished by line wires fed by generators located at power houses, which may be a good many miles apart.

Although alternating current signaling was first

developed to solve difficulties met with in signaling on electric railways, where the running rails are used for the return current, it has been adopted and used widely in steam railway signaling because of its greater safety and also because of a reduction in the amount of maintenance necessary.

The direct current track circuit is generally conceded to have been invented by William Robinson of Brooklyn, N. Y., in 1872. Credit for the development of the alternating current track circuit, or at least for the type of relay which made its use possible, is generally given to J. B. Struble. He invented the vane relay, which responds to an alternating signaling current, but is absolutely free from the possibility of closing its contact when direct current passes through its coils. The first extensive trial of the vane relay and alternating current track circuit was made in about 1903.

Alternating current proved a success in signaling on electric roads, and its safety and economy led to its introduction on steam railroads, the Union Pacific being the first one to install alternating current signaling (in 1906). Many of the roads are now using this system of signaling, and it bids fair gradually to supersede direct current signaling, especially where there are many other electrical circuits and where the danger of foreign current is greatest.

Advantages of Alternating Current—It has been possible, in alternating current signaling, by the use of two-element relays, to give practically complete protection against broken-down insulated joints; also against troubles caused by residual magnetism (which

will cause an armature in a relay to stick and stay closed), because the alternating current apparatus can be made to work upon the induction principle, in which there is no contact between the moving part of a relay and its magnetizing coil.

Track circuits up to 25,000 feet in length can be successfully operated by alternating current. Track batteries are dispensed with, and signal lamps can also be, the lights being lit from the alternating current mains. All this reduces the amount of attention required in maintenance. Furthermore, alternating current can be generated by a generator more cheaply than can direct current by batteries scattered along the roadside.

Interruptions to one part of the signal system are not possible with alternating current signaling, except through line failures, which can be guarded against. It is easy to tell when there is a failure of the current with alternating current generated at a power house. The only way to discover that a battery has unexpectedly gone dead is to go out and make an inspection.

Practically constant voltage can be maintained with A. C. signaling. This is not true with direct current which comes from batteries, and where the voltage constantly drops from the time the cells are renewed until they are exhausted.

Alternating Current Generator—A generator which produces alternating current is called an alternator, and it works upon the same principle as the direct current dynamo. Direct current generators, however, have to be provided with commutators in order to maintain the flow of current constantly in one direction.

No commutator is necessary with the alternating current generator because the direction of the current is not maintained constantly, but, in fact, changes constantly.

Figure 78 shows an end-fed alternating current track circuit. It will be noted that transformers con-

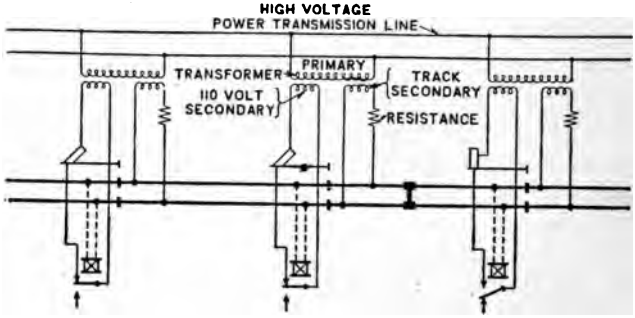


Figure 78—End-Fed Track Circuit.

nected with the power transmission line take the place of the batteries found in direct current signaling.

Briefly, a transformer is an arrangement of coils on iron cores from which we can take off a current of higher or lesser voltage from a power transmission line. In an alternating current track circuit, the coils which feed the track circuits have less turns than the coils which come off the power transmission line. The voltage of the track circuit current is governed by the number of turns of the secondary coils in the transformer. By making these of heavier wire, a corresponding increase in current can be obtained from the secondary windings.

The coils in the transformer do not touch each other, and the secondary coils are energized by "induction"

—that is, by being placed in the magnetic field set up around the primary coil.

Figure 78 is an end-fed track circuit; and it will be noted that from the same primary coil the current is taken off through two secondary coils, one secondary coil feeding the track circuit, and the other feeding the signal circuit.

Figure 79 is a center-fed alternating current track circuit. When feeding from the center, it is not necessary to use such a high voltage, because the voltage drop is measured by the length of the circuit from the source of power to the relay. When power is supplied at the center of the circuit, the distance to the relay (one at each end of the circuit) is only one-half of what it would be were the power applied at one end and the relay placed at the other.

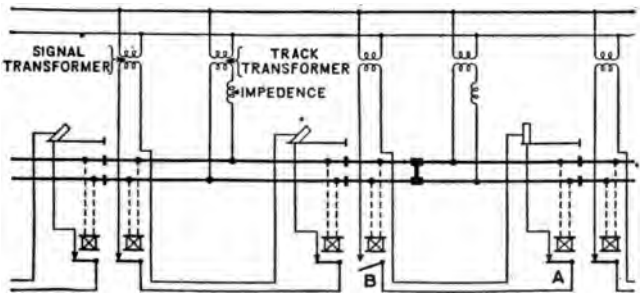


Figure 79—Center-Fed A. C. Track Circuit.

Double-Element Relay—The power which operates a track relay in direct current signaling comes entirely from the current in the track, which is furnished by the track battery. The same is true of the relays in Figures 78 and 79.

But double-element relays have been designed to obviate carrying such a large current in the track

circuit, and their purpose is to help the track circuit current operate the armature of the relay. Thus the track circuit current does not have to do all the work. Part of the attraction for the armature (but not enough to raise it) is furnished by current from a line wire, operating in one element, or coil, of the relay. Therefore it is only the balance of power which must be furnished by the track circuit current. Since only a small amount of power is required in the track element of the two-element relay, comparatively little power is lost in the track circuit. Only a small voltage is necessary at the track transformer end of the track circuit.

Both elements of these two-element relays must be simultaneously energized before any movement is

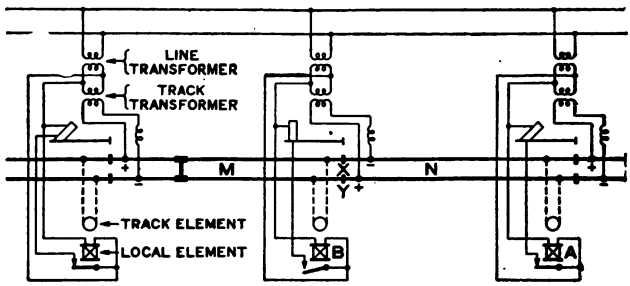


Figure 80—Two-Element Two-Position Relay on an End-Fed Track Circuit.

produced in the moving member of the relay. The line element of the relay is energized all the time, but the track element is only energized when the track circuit is not shorted. Thus the contacts of a two-element track relay will never be closed except when current is flowing through the track element as well as through the line element.

Figure 80 shows a two-element, two-position relay on an end-fed track circuit.

Protection against breakdown in joint insulation is indicated in Figure 80. It will be noted that the polarities of track circuits "M" and "N" are opposite at any given moment. If insulation joints "X" and "Y" were to break down, relay "B" would be forced on its back contacts and thus would open the signal

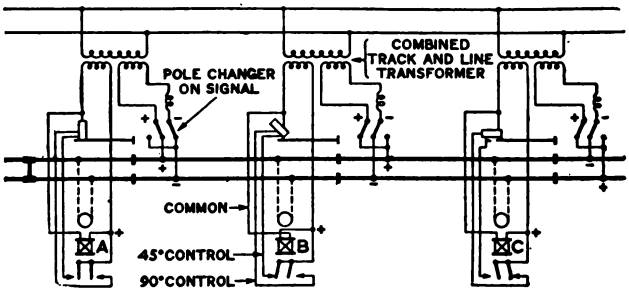


Figure 81—Track Circuits with Three-Position A. C. Relay.

circuit. With a single-element relay, the current in both circuits would be in the same direction, and in case of an insulation breakdown enough current could get around to operate the wrong relay, although an approaching train would shunt this out and cause the signal to indicate "stop."

Figure 81 shows alternating current track circuits where the three-position A. C. track relay takes the place of the polarized track relay used in direct signaling. Tracing through the circuits will show that this three-position A. C. relay fulfills the same functions as the polarized direct current relay.

External Resistance Coil—In the alternating current system the transformer feeding the track has a com-

paratively low internal resistance. Therefore, with alternating current as with caustic soda or lead storage batteries, it is necessary to have an external resistance coil between the transformer and the track to cut down the short circuit current when the track circuit is occupied (shorted). With alternating current this resistance coil performs the same functions as it does with the primary batteries mentioned above—it cuts down the flow of current. In direct current signaling this saves the battery, while in alternating current signaling it saves current and prevents the transformer from being overheated.

Transformers—In transmitting power it is possible to send a given amount of power either by using a large current with a small voltage or by using a small current with a high voltage. In alternating current signaling systems, 2200 volts or higher is used. This voltage, of course, must be stepped down or transformed where used for operating the signal apparatus. A transformer used to take off the high voltage and reduce it to lower voltage is called a "step-down" transformer; and one which receives power at a low voltage and delivers it at a higher voltage is called a "step-up" transformer.

The transformer in the simplest form consists of two coils of wire wound around the same iron core, as indicated in Figure 82. The transfer of power from the primary to the secondary coil is brought about by the magnetic flux produced in the iron ring by the alternating current flowing in the primary coil. This flux, or lines of force, being produced by alternating current, is constantly rising, falling and changing directions. It is thus continually cutting the turns

of wire composing the secondary coil, and in this way inducing an electro-motive force in the secondary.

Transformer Construction—Below we show and describe various types of transformers, as described and illustrated in "Alternating Current Signaling" by Harold McCready.

Types of Transformers—The essential elements of a transformer are the iron core, the coils and their insulations, the terminal board and leadout wires, and the case with its insulation. Depending on the relative arrangement of iron core and coils, transformers may be classified as (a) core type, (b) shell type, or (c) distributed core type. In all cases, of course, the iron core is built up of laminations pointed on both sides to minimize eddy current losses.

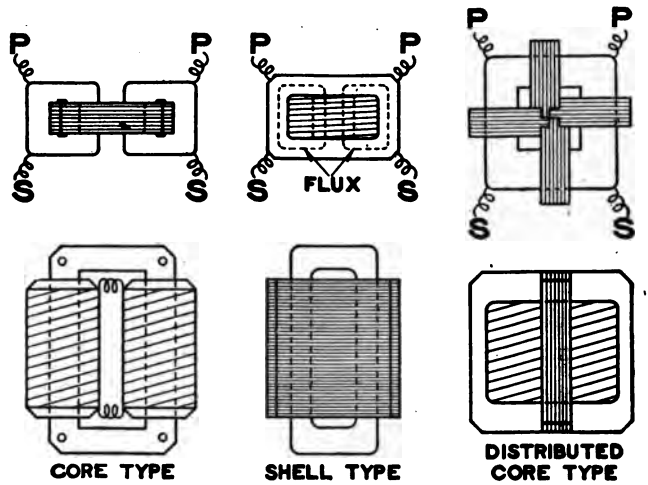


Figure 82—Transformers.

(a) Core type transformers: This construction is illustrated at the left of Figure 82, where it will be seen that both of the vertical legs of the iron core are surrounded by a winding. To cut down magnetic leakage, half of the primary and half of the secondary are wound, one over the other, on each leg, so that the coils may be said to be interlaced.

(b) Shell type: This construction is shown in the middle of Figure 82. Here both primary and secondary are wound interlaced, one with the other, over the center leg of the iron core which almost entirely surrounds the coils. The illustration indicates plainly the fundamental difference in the construction of these various types of transformers.

(c) Distributed core type: This construction, illustrated at the right of Figure 82, is a combination of (a) and (b) above. The iron core consists of four magnetic circuits of equal reluctance, in multiple, and each circuit consists of a separate core. One leg of each magnetic circuit is built up of two different widths of punchings, forming such a cross section that when the four circuits are assembled together, they interlock to form a central leg, upon which the winding is placed. The four remaining outside legs surround the coil at equal distances from the center on the four sides. The complete core, with its coils and terminals, is shown in Figure 83.

As to the relative advantages of core and shell types, it may be said that the core type has a lighter core of smaller sectional area than the shell type, so that more copper with a larger number of turns is

required with the core type, although the turns are of a lesser mean length. Then, again, cylindrical (round) form wound coils can be rapidly wound for the core type, and these coils have a large surface exposed for cooling. Altogether, the core type, with its large available winding space, is better adapted for high voltages which require many turns with considerable space for insulation. The shell type, on the contrary, is particularly suited to transformers of

Figure 83—The Distributed Core with Its Coils and Terminals.

moderate voltage, requiring few turns and little insulation. The distributed core type combines the best features of both core and shell construction: i. e., a short mean length of turn in the coils, and a short length of magnetic circuit. The magnetic circuit is of very low reluctance since the four circuits are all in multiple.

The types of signals used and the method of operation are similar in alternating current signaling and direct current signaling. The operating mechanisms,

the motors, the relays, etc., are different, as are also the devices which hold the signal in position after it has been operated. The actual construction or mechanism of the signal itself is the same. In fact, most signals are so made as to be easily convertible from direct current operation to alternating current operation through a simple interchange of motors and slots.

CHAPTER XIII

OPERATING TRAINS BY SIGNAL INDICATION

AS STATED before, the object of signaling is to expedite traffic and at the same time to promote safety. We have seen how signals do this in the permissive block signal system by allowing trains on double track to follow each other at short intervals and with safety.

We have seen how the capacity of a single-track road may be increased greatly by the installation of an absolute permissive block, which allows following trains to operate on single track exactly as they do on double track under the permissive signal system, but which sets up an absolute stop signal against a train entering a section after the opposing train has entered the section at the opposite end. This prevents any back-up movements such as might be necessary where signals are installed simply with an overlap sufficient to prevent head-on collisions.

All of these methods of expediting traffic, of course, depend upon train dispatching. In other words, the train dispatching must take advantage of the way the signals operate in order to secure the desired benefits.

Superiority of Trains—Trains are superior by right, class and direction: Right is conferred by train order; class and direction by time table. As long as regular trains are proceeding according to schedule, or nearly so, no orders are issued to them (except for some special reason). It is not necessary for a dispatcher to order one train to follow another into a block on a permissive signal. Actually, the following

train would enter the block as soon as the leaving signal displayed a "proceed" indication—"clear" or "caution"—provided the time table and its orders did not conflict with such movement.

In operating trains by signal indication "superiority" of trains is dispensed with and all trains are moved by signal indications in accordance with instructions given by the dispatcher (usually by telephone) to local operators or levermen at interlockings. The advantage of this arrangement is especially apparent in cases where a superior train is behind schedule, which, under the superiority rules, would delay every train on the division if single track, or every train in the same direction if on double track. Under the proposed method of operation, the dispatcher can issue proper instructions as conditions may require from time to time. The ideal method of directing trains is to have (1) automatic block throughout; (2) interlocking plants at each station—the home signals being semi-automatic and interconnected with the automatic block system; (3) all superiority of trains dispensed with; (4) dispatchers to issue instructions to operators or levermen, who direct train movements by (5) signal indications.

No. 31 and No. 19 Train Orders—A form No. 31 order is not completed or made effective until after the conductor has read the order and signed it, and the whole has been repeated to the dispatcher, who then gives "complete." This form, of course, requires the train to stop and wait until the order is "completed."

The No. 31 order affords a high measure of safety and is used mostly in non-automatic block territory in cases where the time-table rights of a superior train

are to be restricted. On account of the high degree of safety provided by automatic signals, the No. 31 order has been largely superseded by the No. 19 train order in automatic block territory.

The No. 19 order is "completed" as soon as it has been repeated back to the dispatcher by the operator, and it is delivered to the engineer and conductor of a moving train, together with a clearance card, both of which are placed on a hoop.

The superiority or rank of trains is well understood by the trainmen on any division, and they realize just what trains have precedence over theirs, and under ordinary circumstances they know about where they must make sidings in order to let superior trains by.

With the intelligent use of this information, supplemented by the knowledge which the trainmen get with respect to the progress of regular and extra trains, it is possible greatly to accelerate traffic by the use of No. 19 train orders, which do not require trains to stop except at stations, or where necessary to let other trains by, rather than No. 31 orders, which require trains to stop and sign even when the next section ahead may be clear and ready for their entrance.

It has been suggested that this acceleration of traffic by the use of the No. 19 order instead of the No. 31 indicates a way whereby train orders may be almost entirely done away with on tracks equipped with the proper system of automatic signaling.

Advantages—There are several points in favor of this method of operation and, of course, some arguments against it. When the engineman receives a train order, it calls for both instant and deferred action, and he is more liable to forget that which calls

for deferred action—as, for instance, meeting a train a good many miles in advance. The indication of the signal calls for no deferred action.

The C. B. and Q. began operating trains on double track between Chicago and Burlington as early as 1900 without written train orders and by signal indication.

Several years' trial showed a large saving in time, because the necessity of waiting for a train of superior class, which might or might not be on time, was reduced. There was a simplification of the train dispatching and also an elimination of the delay caused in waiting for authorization to proceed when an opposing train was delayed and unable to make the assigned passing point.

One of the officials of this road stated in 1911: "Our scheme of running trains on double track by block signals has fulfilled our most sanguine expectations. It has paid our company a great many dollars, I am sure, over the delayful practices of train rules and train dispatches. We have not had an accident of any sort resulting from the change in practice; not a life lost nor a person injured."

It is realized that before the development of the absolute permissive block system for single-track railroads, their operation by signal indication only would probably have led to a good many delays, caused by opposing trains entering the same section at or near the same time, and being stopped by the signal opposing them when they got near together.

The Erie Railroad for several years has been using signals for the directing of traffic on the Susquehanna Division.

In this installation the train-order signals are also operated in three positions. The indications are as follows:

(A) Arm horizontal (displays red light at night). Indication: Stop on main track and consult dispatcher by telephone.

(B) Arm inclined 45 degrees above horizontal (displays yellow light at night). Indication: Take siding and consult dispatcher by telephone when clear of main track. Passenger trains will report before pulling into siding.

(C) 1. Arm inclined 90 degrees above horizontal (displays green light at night). Indication: Proceed regardless of following preferred trains until otherwise directed by dispatcher.

2. Trains are forbidden to accept this indication if there is any known cause which will prevent them from making their usual running time. In such an event, they will consult immediately with dispatcher by telephone. When a train accepts the "proceed" indication, and for any cause is unable to make its usual running time, it must protect itself against the following preferred train according to Rule 99, Operating Department.

(D) 1. It is forbidden to use a crossover at any point where a telephone train-order signal is located without permission from the dispatcher.

2. When trains approach interlocking points with insufficient time to clear the schedule of a superior train at next passing point, the whistle must be sounded for siding; and if "proceed" signals are displayed, trains will proceed in accordance with paragraph "C."

The indications of these train-order signals, together with the automatic block signals, have greatly facilitated traffic and reduced unnecessary stops of trains to a minimum.

The dispatcher directs late trains or extra trains by sending telephone instructions to the signalman at the train-order offices. The train-order signals are operated in accordance with these instructions.

Increased Responsibility—This chapter may appear to deal more with train operation than with signaling; yet it is plain to all of us that the greater the dependence placed upon signals, the more careful we must be in their maintenance, in order that the acceleration of traffic may be realized. The operation of trains by signal indication makes the signals more important than ever before. The more important the work of the signal department, the greater is the responsibility upon the shoulders of every man who is assigned to the work of signal maintenance.

And with this increased responsibility, of course, should come increased skill and better working conditions, so that all may participate in the benefits which would follow from such improved operation.

CHAPTER XIV

AUTOMATIC TRAIN CONTROL AND AUTOMATIC STOPS

THERE is probably nothing in recent years that has caused as much diversity of opinion as the question of automatic train control and automatic stops. The argument against both automatic train control and automatic stops is that their installation decreases the responsibility of the engineman and trainman and thus promotes carelessness.

Difference Between Automatic Train Control and Automatic Stops—Probably the first thing to get definitely in mind is the difference between automatic train control and automatic stops. The automatic stop is a device which applies the air brake, giving either a service or an emergency application, and thus tends to bring the train to a stop. The automatic train control is an apparatus designed to reduce the speed of a train to a certain rate, in case the condition of the block justifies a cautionary speed, or to bring the train to a stop, provided the block in advance is occupied. Therefore, with automatic train control we would stop the train if the conditions were such that a stop signal would be displayed, but would allow it to proceed at a safe speed if the conditions were such that a caution signal would be displayed.

An automatic stop operates only when a stop signal would be displayed, while automatic train control

operates in accordance with both the "caution" and the "stop" indications of a signal.

There has been a great deal of controversy as to which of the two, automatic stops or automatic train control, should be used in case it were decided to use one or the other. Advocates of automatic train control claim that to control the speed of the train in accordance with cautionary indications will greatly facilitate the movement of traffic and increase safety; and advocates of the pure automatic stop claim that automatic train control is too complicated and that it is not necessary to take the control of the train away from the engineman until he is confronted with what would be a "stop" indication.

There is still further difference of opinion as to when control of the train should be taken away from the engineman. Some argue that after the air has been once applied, and the engineman has thus been warned that there is danger ahead, he should be free to control the further operation of the train, bringing it to a complete stop or reducing its speed to a safe rate. Others argue that after the brakes are once applied, the engineman should be prevented from regaining control of the train until it has been brought to a complete stop.

Most advocates of train control or automatic stops are advocating them as an addition to, and not as a substitute for, automatic signals.

Classification of Methods—The automatic train control committee of the Interstate Commerce Commission classified the methods of operating train control as shown in the following table:

Character of Control	*Class of Device*	*Type of Device*
I. Intermittent.	A. Contact.	1. Plain mechanical trip. Ground or overhead.
		2. Electrically controlled mechanical trip. Ground or overhead.
		3. Intermittent electric contact.
	B. Track rail contact.	1. Insulated truck with short track circuit section.
	C. Non-contact.	1. Induction.
		2. Inert roadside element.
		3. Non - magnetic rail.
II. Continuous.	A. Contact.	1. Third rail or special conductor.
	B. Non-contact.	1. Induction.
		2. Wireless.

General Requirements—Several years ago the automatic train control committee also laid down general requirements for automatic train control and automatic stops, which are as follows:

1. The apparatus shall be so constructed as to operate in connection with a system of fixed block or interlocking signals, and so interconnected with the fixed signal system as to perform its intended functions: (a) in the event of failure of the engineman to obey the fixed signal indications, and (b) so far as possible when the fixed signal fails to indicate a condition requiring an application of the brakes.

2. The apparatus shall be so constructed that it will perform its intended functions if an essential part fails or is removed; or a break, cross, ground or failure of energy occurs in electric circuits, when used.

3. The apparatus shall be so constructed as to make indications of the fixed signal depend upon the operation of the track element of the train control device.

4. The apparatus shall be so constructed that proper operative relation between those parts along the roadway and those on the train will be assured under all conditions of speed, weather, wear, oscillation and shock.

5. The apparatus shall be so constructed as to prevent the release of the brakes after automatic application, until the train has been brought to a stop, or its speed has been reduced to a predetermined rate, or the obstruction or other condition that caused the brake application has been removed.

6. The train apparatus shall be so constructed that when operated it will make an application of the brakes sufficient to stop the train or control its speed.

7. The apparatus shall be so constructed as not to interfere with the application of the brakes by the engineman's brake valve or to impair the efficiency of the air brake.

8. The apparatus shall be so constructed that it may be applied so as to be operative when the engine is running forward or backward.

9. The apparatus shall be so constructed that when two or more engines are coupled together or a pusher is used, it can be made operative only on the engine from which the brakes are controlled.

10. The apparatus shall be so constructed that it will operate under all weather conditions which permit train movements.

11. The apparatus shall be so constructed as to conform to established clearances for equipment and structures.

12. The apparatus shall be so constructed and installed that it will not constitute a source of danger to trainmen, other employees, or passengers.

The Regan Train Control—While there have not been a great many actual installations of train control or automatic stops, the Regan train control has been in service on the Rock Island for a considerable period.

The Regan train control is comprised of two elements: the locomotive and tender equipment and the apparatus located on the roadside. The locomotive and tender equipment consists essentially of a speed circuit controller, an electro pneumatic valve, a shoe mechanism, a relay, a storage battery, a release key, the necessary conduits and wiring for the electric circuits, and, when desired, visual or audible cab signals. The illustration shows the arrangement of the various parts as installed on locomotives of the Chicago, Rock Island and Pacific Railroad. The roadside equipment consists of a specially designed ramp and the necessary connections.

The locomotive and tender equipment is so arranged and interconnected as to cause the shoe stem to pick up from the roadside apparatus an indication of the proper characteristic to actuate the relay to one of three positions, namely, "full proceed," "caution," and "stop." As the shoe rides up the inclined surface of the ramp, it moves the electric circuit controller and thus disconnects

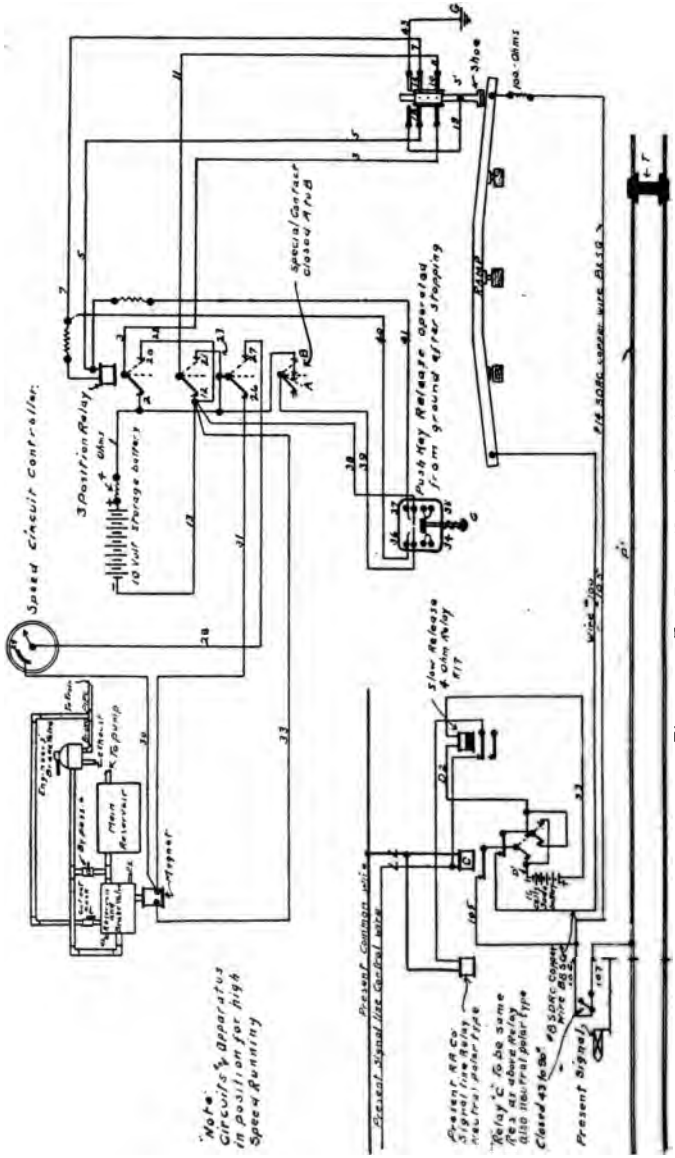

Speed Circuit Controller
3 Position Relay
10 Volt Storage battery
Special Contact closed After
Push Key Release operated from ground after Stopping
Shoe
Rail
Main Reservoir
Air Pump
Present Signal Line Control wire
Present Comm. wire
Present RR Co. Signal line Relay Neutral polar type
Relay "L" to be same as above Relay also Neutral polar type
Present Signal
Wire Base
Note: Circuits for Apparatus in position for high Speed Running

Figure 84—The Regan Train Control.

the storage battery, and at the same time it connects the ramp circuit, which remains connected during the travel of the shoe over the horizontal surface of the ramp. As the shoe rides down the inclined surface at the leaving end of the ramp, the storage battery is again connected and the roadway circuit cut off.

When a full "proceed" or "caution" indication is received, the storage battery thereafter supplies energy to the locomotive and tender equipment to maintain the indication received, until the characteristic of the current is changed to actuate the relay to the other position or to stop the train, as the case may be; but the storage battery is cut off from the circuit and energy from the roadside is substituted momentarily at each signal or ramp location, the condition of the roadside and locomotive and tender equipment being checked in this way.

When the locomotive and tender equipment is actuated to the full "proceed" position, the storage battery supplies energy to the magnet of the electro pneumatic valve through a circuit controller directly connected to the stem of the shoe mechanism; and this actuates the valve so that it closes the brake pipe vent and opens the reservoir supply to the engineman's brake valve. In the full "proceed" position, the speed circuit controller is cut out from the circuit entirely.

When the character of the current is changed by the roadway apparatus, and the locomotive and tender equipment is actuated to the "caution" position, the circuit is as above described, except that the speed circuit controller is automatically connected into the circuit. If a train exceeds the predetermined speed for which the speed circuit controller is adjusted, the controller

operates to de-energize the electro pneumatic valve and thus opens the brake pipe vent and causes a service application of the brakes. The reservoir supply is closed at the same time to prevent the brakes from being released by the engineman's brake valve. When the speed has been reduced to the point at which the controller is set, the controller operates to close the electric circuit, thus again energizing the magnet of the electro pneumatic valve, closing the brake pipe vent, and restoring the brakes.

A "caution" indication having been received, the speed is automatically closely restricted throughout the caution block to the predetermined point at which the controller is adjusted, the brakes applying automatically whenever the train exceeds the predetermined speed and releasing automatically whenever the speed is reduced to the proper point. In actual service it is found that the engineman quickly learns how best to operate under speed control, and that the train is ordinarily held just below the predetermined speed.

In the operation of this system an application of the brakes is made by the automatic control apparatus when any of the following conditions exist:

(a) When a train passes a signal in the "caution" position, or a ramp carrying the "caution" characteristic, at excessive speed.

(b) Whenever a train exceeds the predetermined speed while running in a caution block or over limited speed territory.

(c) At a stop signal or de-energized ramp.

When an automatic application of the brakes is made by the control system, the brakes may be released, with

the device in service, only by one of three methods, as follows:

1. By automatic release, as in caution or limited territory, when the speed is below that for which the speed controller is set.

2. By automatic release as when passing over caution or limited speed territory to a clear block or to unlimited speed territory.

3. By operating the release switch to pass a stop signal or a de-energized ramp.

In order to proceed after having been brought to an automatic stop, or in order to pass a "stop" indication, it is necessary for the engineman to operate a release switch. The train may then proceed, but only under automatic speed control, until the next ramp location is encountered, when, if the block be clear, unlimited speed will be restored.

Speed Circuit Controller—The speed control mechanism is housed in a case which is attached to the locomotive. It consists essentially of one part which revolves with the axle to which it is connected, and another part which is arranged for connection with the locomotive circuit by means of a flexible conduit. Ball or roller bearings are provided to reduce friction and to guard against undue strain on the flexible connection.

The speed controller is of the centrifugal type. The governor is mounted upon a base plate which is bolted to the end of the axle of the pony wheels and centered with the axle, and the counter bore in the axle is fitted with a projection from the main stem supporting the governor. As the wheel revolves, the centrifugal governor operates a circuit controlling device, which is

adjusted to any predetermined speed, depending upon the class of service to which the locomotive is assigned. Connection to the circuit is made by means of fixed contact springs and binding posts properly insulated.

It is evident that automatic speed control may be installed to advantage where safe operation on permanent slow track is desired—as on sharp curves or at other locations where limited speed is required—and where it is deemed advisable to set a maximum limit as to speed, as on inferior branch lines or on trains of a certain class. When used in this way it requires no roadside connections. With a battery, an electro-pneumatic valve, and the necessary connections, it constitutes a complete maximum speed control system.

Shoe Mechanism—The shoe mechanism is mounted upon the arch bar of the tender truck or fastened to the trailer truck of the locomotive. It consists of a shoe stem, a cylinder, and a circuit controller, all housed in a cast steel case. The circuit controller is attached directly to the shoe stem, which in its travel over the ramp moves a sufficient distance to supply ample movement for selecting between the locomotive and the roadway energy. Protection for the circuit is provided by a flexible conduit connected from the housing to the fixed conduit on the locomotive.

The shoe stem is held in position for contact with the ramp by means of the cylinder into which the upper part of the shoe stem is fitted, this cylinder being directly connected to the brake pipe, so that the shoe stem is held in the "down" position under pressure. When the shoe contacts with the ramp, constant pressure is available throughout the movement, the brake pipe acting as

a reservoir to receive the volume of air displaced from the cylinder and to restore the shoe stem to its normal position. The shoe stem is also directly connected with the brake pipe, and it is drilled almost throughout its length to insure a service application of the brakes in case it should be broken off.

A bolt lock is provided for fastening the shoe stem in the "up" position if it is desired to operate a locomotive fitted with train control equipment outside of train control territory. When the stem is so secured, the locomotive circuit is de-energized, and energy from the storage battery is thus conserved.

Roadside Apparatus—The roadside apparatus consists of a ramp, a battery, a relay, and the wiring necessary to connect the ramp with the signal system or with the track circuits, or with both, as the case may be. The ramp is of special design and is built of angle iron with a copper insert. It is mounted upon cast iron supports bolted to standard ties, being separated from these supports by a suitable block or wood stringer. It is made with an incline at each end to insure proper movement of the shoe mechanism. The battery and the relays are standard types used in signal work.

The Miller Stop—The Miller automatic stop has been installed upon the C. E. I. Railroad for several years. This installation simply applies the air on the locomotive where a ramp indication is received which would correspond to the "stop" indication of the signal.

The apparatus is so arranged that, after the air has been once applied, the engineman may manipulate his air as he sees fit. He can immediately regain control of his train after the air has been automatically applied.

The main features of the Miller train control are a ramp on the roadside connected in an electric circuit, a contact shoe on the locomotive, a relay in the locomotive cab, and the necessary circuits. The contact shoe is raised every time it passes a ramp. If the ramp is energized, an electric circuit is set up through the ramp, the shoe of the locomotive and the relay in the locomotive cab.

When the shoe of the Miller automatic stop rises, it tends to open the air line and apply the brakes. How-

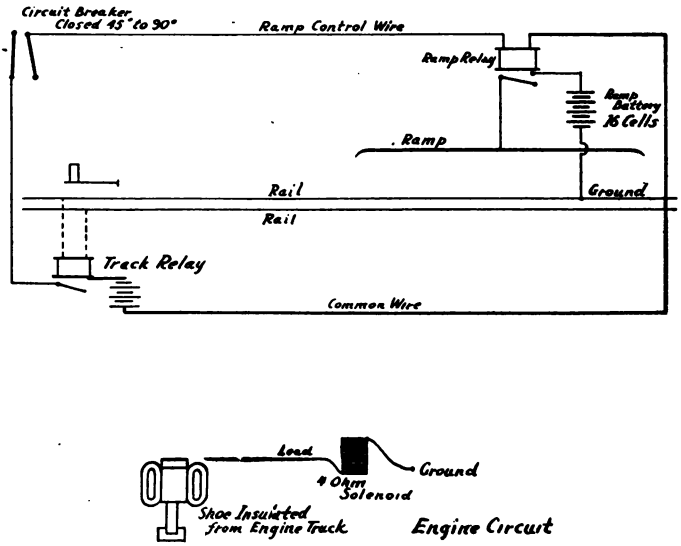


Figure 85—Miller Train Control. Typical Circuit with Ramp De-energized.

ever, when the ramp is energized, the electric current which comes through the ramp and the shoe to the electro-magnet in the cab raises the armature of this electro-magnet and thus opens another port, so ar-

ranged that the opening in the air line caused by the mechanical raising of the contact shoe is balanced. Thus, if the block ahead is unoccupied, the roadside ramp is energized, the action of the shoe in rising is counteracted by the picking up of the relay armature in the cab, and there is no application of the brakes.

But if there is a train in the block ahead, or there is a broken rail or other conditions which would cause the signal to display the "stop" indication, the ramp will be de-energized just as the track circuit relay is de-energized, no current will pass through the ramp and the shoe to the relay, there will be no counteraction of the opening of the air line, and the brakes will apply.

The ramp circuit is controlled through both the relay of the track circuit and the relay of the signal, so that in case either of these circuits fail, the ramp circuit will also fail and the brakes will be applied.

The ramps of the Miller train control are not located at the signals. They are located braking distance in advance of the signals, so that if a signal is in the "stop" position a train will receive an automatic brake application before it arrives at the signal location. Braking distance is so figured as to stop the train with the service application of the brakes by the time it gets to the signal in the "stop" position; and this distance is figured for the highest speed trains and most unfavorable track conditions.

In effect, this gives a protection similar to that given by a home and distant signal installation. The brakes are applied automatically at a point where a distant signal would have indicated "caution" when the home signal was at "stop." Thus in a measure the Miller train con-

trol resembles a three-indication system where the ramp gives the "caution" indication when the signal itself shows the "stop" indication.

Shadle Automatic Signal and Stop System—The Shadle automatic signal and stop system is of the intermittent electrical contact type, with sixty-foot ramp rails located in advance of the signals. There is an installation of this train control on the C. I. & W. R. R. in absolute permissive block single track line. The engine, in addition to the automatic service brake valve, has a speed control device for holding the brakes until the train speed has been reduced to a predetermined rate.

Upon operating a block displaying the "caution" indication, two applications of the brakes are made automatically through the engineer's brake valve, and the train speed is thus reduced to the predetermined rate and held below this rate through the rest of the block. Upon operating a block protected by a "stop" indication, a further application of the brakes is made and the train is brought to a full stop.

The speed control apparatus in this system is independent of the automatic control equipment, and a failure of the speed control has no effect on the automatic control and stop system. The operating equipment consists of three electro-magnets, which operate circuit controllers, located in an iron box suspended under the body of the tender tank. One of these magnets has four different windings, and this magnet gives the speed control. A second magnet is for the pick-up from the ramps. The third magnet is for maintaining the automatic control equipment inoperative when the block is clear.

The speed control is accomplished by what is called a

"tachometer," driven by a flexible connection attached to one of the axles of the engine truck.

When a train encounters a "caution" indication, the movement of the ramp shoe will cause an automatic service application of the air brakes, bringing the speed of the train down to the "caution" speed and preventing this speed from being exceeded until another signal has been passed. When the train encounters a "stop" signal, the movement of the shoe on the ramp causes a service application of the brakes, which will bring the train to a complete stop.

American Automatic Train Control—The American automatic train control is installed on twenty-one miles of main line on the Chesapeake and Ohio Railroad—on a single track section between Gordonsville and Charlottesville, Virginia. All freight and passenger engines (forty-one) are equipped with the control, which has been in operation for three years, and the C. & O. has now contracted for a forty-mile extension to this installation.

The American automatic train control was designed to solve the following problems:

1. Meeting train movements on single track without reducing the capacity of track.

2. Reducing the obstructing of roadbed to a minimum by the use of ramp rails only forty feet in length, from which both automatic stop and cab signals are operated.

3. Controlling speed of train by electrically operated speed control, in place of speed control operated by mechanical means.

4. Reducing to a minimum the time consumed in stopping and starting a train when stopped by automatic application of brakes.

5. Producing an equipment that will stand up under the constant rough usage of regular service operation (having only one moving part).

6. Transmitting condition of track circuits into engine cab with lights and whistles to call attention of engineer.

With this train control the operation of the air brakes is not taken out of the engineer's hands until he has had every opportunity to obey the signals.

The present installation covers twenty-one miles of single track main line; and the train control is designed on the absolute permissive block system principle, giving absolute protection against approaching trains and permissive protection against following trains. Speed control features were not included in the C. & O. installation mentioned.

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